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34-36

1909.

WESTERN AUSTRALIA.

From the Government Geologist's Compliments.

GEOLOGICAL SURVEY.

BULLETIN No. 34.

REPORT UPON THE AURIFEROUS DEPOSITS OF BARRAMBIE AND ERROLLS (Cue District) AND GUM CREEK (Nannine District) IN THE MURCHISON GOLDFIELD; ALSO WILUNA (Lawlers District) IN THE EAST MURCHISON GOLDFIELD.

BY

CHAS. G. GIBSON, B.E.,

ASSISTANT GEOLOGIST.

Issued under the authority of the Hon. H. Gregory, M.L.A., Minister for Mines.

WITH TWO MAPS, THREE PLATES, AND SIX PHOTOGRAPHS.

PERTH:

BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.

1909.

Geological Maps, Reports, and Bulletins issued by the Geological Survey of Western Australia.

I.—MAPS.

Geological Map of Northampton: by A. Gibb Maitland. Scale, 20 chains per inch. Two sheets. Price, 2s. 6d. 1898.

Geological Map of Coolgardie: by T. Blatchford and E. G. Allhusen. Scale, 16 chains per inch. Four sheets. Price, 10s. 1898.

Topographical Map of Kalgoorlie: by W. D. Campbell and S. J. Beeber. Scale, 16 chains per inch. Four sheets. Price, 5s. 1900.

Mining Map of the Boulder Belt: by W. D. Campbell. Scale, 4 chains per inch. Two sheets. Price, 5s. 1900.

Geological Map of the North Lead, Kanowna: by Torrington Blatchford. Scale, 8 chains per inch. Price, 1s. 1901.

Geological Map of Kalgoorlie: by A. Gibb Maitland and W. D. Campbell. Scale, 10 chains per inch. Six sheets. Price, 21s. 1902.

Geological Map of the Boulder Belt and Sheet of Horizontal Sections: by A. Gibb Maitland and W. D. Campbell. Scale, 4 chains per inch. Three sheets. Price, 12s. 6d. 1903.

In preparation:

Geological Sketch Map of Western Australia: by A. Gibb Maitland. Scale, 1/1,584,000. Four sheets.

II.—REPORTS.

Reports by the Government Geologist in connection with the Water Supply of the Goldfields, containing—

(a.) Coolgardie and Kalgoorlie.

(b.) Menzies.

(c.) Cue. Price, 1s. 1897.

Annual Progress Report for the Year 1897. (*Out of print.*) 1898.

Annual Progress Report for the Year 1898, containing—

Location 1830, Avon District; Gold Discoveries on the Ditchingham Estate, Brunswick River; Collie Coalfield; Proposed Boring for Artesian Water in the Eastern Agricultural Districts; The Country between Cape Riche and Albany; The Wongan Hills; The Artesian Water prospects of the vicinity of Moora; A Geological Reconnaissance of the Country at the heads of the Murchison and Sandford Rivers, in the Murchison, East Murchison, and Peak Hill Goldfields; Gold Discoveries at Donnybrook; Norseman Public Battery, and the use of Briquettes in Gold Extraction; Mineral Waters; Mineralogical and Petrological Notes; Kalgoorlie; Menzies. Price, 1s. 1899.

Annual Progress Report for the Year 1899, containing—

Notes on the Greenbushes Tinfield; Boring for Water at Mulgarrie; Boring for Water at Hayes' New Find; The Geology of the Bardoc District; On the Development of Mining in the locality of Donnybrook; The Geology of the North Lead, Kanowna; The Kanowna Great Boulder, G.M.L. 885x; Mineral Waters; Composition of Native Gold; Greenbushes Tin Ore; Cobalt Ores; Menzies Goldfield; Kalgoorlie Goldfield; Coolgardie Goldfield. Price, 1s. 1900.

Annual Progress Reports for the Year 1900, containing—

Kalgoorlie Goldfield; Phillips River Goldfield; Gold Finds on the Preston and Ferguson Rivers; The Present Condition and Future Prospects of the Greenbushes Tinfield; Boring for Coal near Albany; North Lead, Kanowna; Ruling Deep Leads; Coolgardie Deep Leads; Alluvial Deposits, Donnybrook Goldfield; Subsidy to the Norseman Gold Mines, Ltd.; Gascoyne District; Extension of Artesian Water-carrying Strata from South Australia. Price, 1s. 1901.

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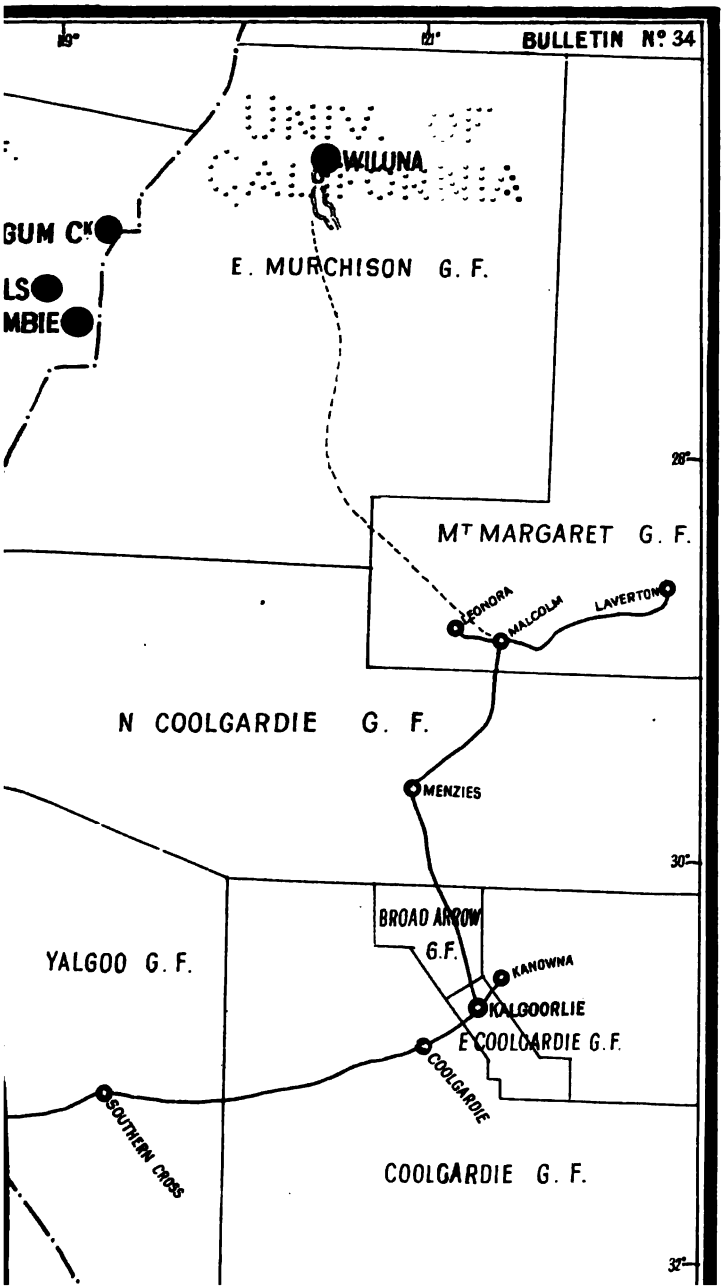

1908.

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OF

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PREFATORY NOTE.

These reports upon certain centres in the Murchison and East Murchison Goldfields are the result of an examination made during the year by Mr. C. G. Gibson whilst engaged in mapping in upon broader lines the geological features of the latter field. As, however, his services were required as Geologist attached to the Transcontinental Railway Survey, it was found necessary to recall him before this work was completed.

Upon his journey across from Nannine he passed Barrambie and Errolls, the auriferous belt of which he describes as consisting of a chloritic schistose zone, enclosed in granite country of some 10 miles in length and three miles in width. The rocks of this area he considers belong to the acidic series, in which case they most probably are the result of the alteration and shearing of granodiorites similar to those carrying the auriferous lodes in the Cue district.

At Errolls the quartz lodes are apparently of the usual lenticular type met with in foliated rocks which, although often attaining considerable size in places, are not usually of any considerable longitudinal extent, whilst this same remark will in all probability apply to their vertical continuity.

At Barrambie, upon the other hand, the lodes although small apparently follow searing planes, and can be traced for a considerable length at the surface, and therefore give greater promise with regard to their permanency in depth.

In the Gum Creek district there appears to be a fairly extensive auriferous area, but, although a considerable quantity of stone has been crushed, which yielded over one ounce of fine gold to the ton, little is doing in this locality at the present time.

It is ten years since Mr. Blatchford, then Assistant Government Geologist, reported upon the Lake Way district, which is now known as Wiluna, and in consequence Mr. Gibson's report will be read with considerable interest, particularly as a new class of auriferous deposits is now being developed. He described the district as consisting entirely of greenstone schists, which class of rock extends over an area of some 1,240 square miles, for although they do not always appear at the surface they will be met with in sinking at a moderate depth. These greenstones, although very similar in appearance to those usually met with upon the other goldfields, are of a more highly siliceous character, thus more nearly approach quartz-diorite.

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The auriferous portion of this tract of country is apparently confined to a belt some three miles in length by one mile in width, having a North-westerly course, which direction is also followed by the quartz reefs which occur in lines having considerable length and degree of parallelism; they are not, however, continuous sheets, but a series of lenticular bodies the edges of which often over-lap one another, which character is common to these deposits in schistose country.

Besides the quartz reefs there are a series of so-called lodes which have more recently been discovered in this district to carry payable values in gold. These consist of zones of highly foliated or crushed rock, one series of which follows a parallel course to the reefs, whilst the other crosses them at about right angles. In this class of deposit the solutions have apparently found a free passage through the folii of the rocks upon the faces of which gold has been deposited, associated in places with large bunches of sulphide of Antimony said to be highly auriferous.

Acidic dykes are not of common occurrence, but two, composed of granite, are met with in the centre of the auriferous belt, whilst basic dykes, owing to their similarity to the altered greenstones, have not been observed at the surface; but Mr. Gibson mentions some belts of more highly foliated rocks which vary from a few feet to several chains in width, following a course a little to the west of north, which may possibly belong to this class.

The quartz bodies do not apparently carry gold values consistently throughout, but are sometimes richer upon one wall and sometimes upon the other, although in exceptional places the whole width of the vein pays to crush. The conclusion he arrives at is that although it is probable that these planes of quartz lenses will extend to a considerable depth, the values in gold will probably diminish below the zone of secondary enrichment; upon the other hand he speaks highly of the lodes of which he considers there is very considerable prospect of greater permanency in depth although probably not quite so rich as above the water level.

HARRY P. WOODWARD.

Acting Government Geologist.

Geological Survey Office,
Perth, 4th September, 1908.

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WILUNA.

The town of Wiluna is situated about a hundred and twenty miles slightly north of east of Nannine, which is the nearest railway station, and to which it is connected by a weekly coach service.

The only detailed report which has been previously made on the district is that by the then Assistant Government Geologist (Mr. Blatchford), who examined and reported on the field in 1898. His report, together with an explanatory geological map, appears in the Annual Report of the Geological Survey for the year 1898, in which he states that he "was at once struck with the similarity of the enclosing country rocks, which in all cases where they outcropped proved to be either granite or mica and quartz schists, the latter arising, no doubt, from the metamorphism of the former."

Personal observations have proved these so-called mica schists to be merely a silicified and weathered belt of greenstone schists, the rock in the main being the same right throughout the district.

As Mr. Blatchford during his visit examined a number of mine workings which at the time of my visit were inaccessible, I have in this report made partial use of his descriptions when dealing with some of the mines in question.

There is a large extent of auriferous country, the belt being first entered on, when travelling in an easterly direction, at Mt. Merewether, about twenty-five miles from Wiluna, and extending for at least six miles beyond that place, but how much farther is not known. It extends to the north and south from a point some five or six miles south of Mt. Laurence Wells to about twenty miles north of Wiluna, being a total length of at least forty miles.

The greater part of this area is covered with the ubiquitous recent deposits, often to a considerable depth, but at Mt. Merewether, and from thence north-easterly there is a considerable extent of hilly country where the rocks outcrop, and which should be well worthy of the prospector's attention; near Mt. Laurence Wells, also, there is a nice looking patch of country which, however, appears to have been fairly well prospected, but with what results I was unable to learn.

In the neighbourhood of Wiluna townsite, covering the area over which the leases extend, and also for some miles northward the country is somewhat hilly, series of low rounded greenstone ridges rising to a height of about one hundred feet; south and west, however, are extensive flats which have a general fall southerly into Lake Way.

The rocks comprising this auriferous belt are similar to those at Gum Creek and Montague, and practically the same as found on all the Western Australian Goldfields, the only difference being that those of the Wiluna belt are apparently slightly more acidic than those of the fields farther south. They are as a rule massive and fairly fined grained, and consist of hornblende rocks often approaching quartz diorite in composition.

In the Wiluna district well defined narrow belts of schists are frequently found traversing the main greenstone body; these usually run on a bearing slightly west of north, and vary in width from a few feet to several chains; they are merely crushed zones of country rock and apparently mark old main fault, or shear, lines, and it is generally along them that the main lines of quartz reefs and lodes occur.

These schists are usually much weathered at the surface, and frequently considerably silicified, in which cases they closely resemble in appearance a crushed granite or quartz porphyry.

The ore deposits of Wiluna fall naturally into two main classes, viz.:—

(a.) The Quartz Reefs,
(b.) The Lodes.

Of these the latter are at the present time of by far the greater economic importance, as it is upon them that the permanency of the district depends.

The Quartz Reefs.—By reference to the accompanying map of Wiluna, it will be seen that the quartz reefs exhibit a very marked degree of parallelism, and also that they fall into two main groups, an eastern and a western.

The eastern group includes the Caledonia, Black Swan, Try Again, and Lake Way lines of reef, with their southerly extension; whilst the western group includes the Monarch, Lady of the Lake, Weeloona, and Golden Age lines. At the south end of the field is a third main parallel series, including the Lawler's reef, and what is known as the "Buck" reef of the Gwalia Consolidated; this series probably is the continuation of a well defined line occurring at the north end of the field in the Lady Margaretta and Derwent leases.

Within these groups the individual reefs are often of great size, frequently reaching twenty feet in thickness, and rising as conspicuous hills of quartz to as much as 40 or 50 feet above the surrounding country; at times they outcrop as continuous bodies of quartz for a distance of fully a mile, and at others they consist of a series of lenticular bodies of varying length, these sometimes overlap and at others are separated by a distance of over a chain. In the case of this latter class of reef the quartz bodies as a rule do not occur in an exact straight line, but lie either to the right or to the left, the displacement usually varying from half-a-chain to one chain. Even when the reefs outcrop continuously they exhibit a marked lenticular habit.

In many cases the quartz lenses owe their displacement to small cross faults, these being often marked by small veins of quartz, but this does not appear to be always the case; several of these small cross faults are especially well marked in the case of the Lake Way reef.

All the quartz reefs occur within well defined narrow belts of schist which mark main shearing, or fault, lines; these schists are

best defined and most noticeable along the line of the lenticular quartz bodies and are particularly well developed along the Weeloona line.

The best idea of the general extent, etc., of these reefs can be got by a reference to the map herewith.

In this District attention was first paid to the quartz reefs which have been worked on and off for twelve years, but little or nothing has been done below a vertical depth of 250 feet, and at the present time most of the work is being carried on by small parties of men who are "picking" crushings from near the surface.

Generally speaking, developments have not proved very satisfactory, for although the reefs are large the gold occurs only in small and irregular shoots, whilst the bulk of the stone is too poor to crush. These shoots, which apparently have a tendency to cut out at a shallow depth, occur usually near the walls of the reefs, sometimes on the hanging and sometimes on the footwall, whilst at times the whole width of the reef carries payable values

As far as development in depth has gone the reefs, though exhibiting their lenticular habit vertically as well as horizontally, show no signs of cutting out and personally I think they should live to a very considerable depth; the permanency of the quartz, however, is of very little economic importance if the gold should cut out, and, unfortunately, so far such appears to be the tendency.

A fuller description of the individual quartz reefs will be found under the heading of the leases on which they have been worked.

The Lodes.—These have been worked principally towards the southern end of the district where, in addition to occurring in parallel series with the main lines of quartz reefs, they are found running practically at right angles to them, the two series probably having an intimate connection.

The lodes consist of zones of crushed rock marking old fault, or shear, lines along which the country rock has been crushed and shattered over a considerable width, and cleavage planes and cracks have been formed, along which gold-bearing solutions have had access. Within the weathered zone near the surface the extent of this shattering with its resultant cracks has been very considerable and, the rocks being soft, the gold-bearing solutions have to a certain extent been able to percolate on either side of the cracks and fissures, thus impregnating the country rock over considerable areas; this accounts for the apparent great size of the ore bodies and their irregularity near the surface, the gold values being naturally higher where the cracks and cleavages are most numerous and low in those parts which have to a greater extent resisted crushing and fracturing. At a depth, when more settled and unweathered country is met with, the lateral extent of these ore bodies will probably be found to become considerably less and the values to follow well defined channels instead of, as in the present workings, being disseminated through considerable widths of weathered country.

These channels are of undoubtedly deep-seated origin and there need be no fear whatever as to the probable permanency of the ore bodies; whether or not the gold values will live down with them is a matter which can only be definitely settled by actual deep work. Allowing for a certain decrease owing to the enrichment within the zone of oxidation there is no reason whatever why they should not do so.

The series of shear (fault ?) lines along which these ore bodies occur appears to be part of that along which the large quartz reefs are found, since, in one or two instances, the quartz reefs can be seen on the surface to die out and give place to the typical lode formations.

In these lodes are frequently found small deposits of massive stibnite (sulphide of antimony) which are said to be high in gold contents, but so far no effort has been made to treat them. Their occurrence seems to be restricted entirely to the lodes for, as far as I was able to learn, stibnite has not been found in any of the quartz reefs. It is not as a rule found disseminated in small quantities throughout the ore but usually occurs in small lenticular bodies containing up to perhaps a ton or more, and can thus be easily separated from the ore and put aside; consequently it does not interfere to any great extent in the metallurgical treatment of the ore. Samples of stibnite are said to have assayed as high as 17ozs. of gold per ton, but this appears to be exceptional.

It is only comparatively recently that these lodes have been worked in the district and nothing has been done on them to any depth; on the Gwalia Consolidated, which is the oldest line worked, the workings are all at the 100 feet level and on none of the other lines has anything been done at a greater depth.

Systematic prospecting should result in the discovery of many other of these "lodes" as the schist belts (shear lines) along which they occur are plentiful and well defined, and it is therefore only natural to assume that other payable ore bodies will be met with along them.

Alluvial Gold.—A few small patches have been worked at the south end of the district for alluvial, or more correctly speaking, detrital, gold where it appears to have been obtained within a few inches of the surface, and several good sized pieces are said to have been found. The patches have long since been worked out and nothing is being done in this line now.

Water Supply.—The district as a whole is well supplied with water; at the north end of the field this is fresh, but at the south end, towards Lake Way, it is salt and the level is only about thirty feet but the supply is inexhaustible. Towards the north end the level varies from 50 to 80 feet and the supply is plentiful.

It is only in the vicinity of the Lake that salt water is met with, the supply throughout the field, as a whole, being fresh.

Timber.—Timber is somewhat scarce in this district, and the supply is practically all mulga, the best being rapidly cut out; there

is, however, a fair amount of firewood still available. A little gum timber is procured along the creek beds, but the supply is very limited.

Table showing the Yield from the Wiluna Mining Centre up to the end of 1907.

Year.	Ore crushed.	Gold therefrom.	Rate per ton.
	tons.	ozs.	ozs.
1897	40.00	*296.70	7.41
1898	2,473.55	†3,066.68	1.24
1899	6,101.35	‡4,748.29	.78
1900	15,541.00	10,567.70	.68
1901	6,715.00	7,255.73	1.08
1902	30,648.00	13,696.86	.45
1903	23,816.00	9,274.17	.39
1904	13,097.50	9,526.37	.73
1905	20,408.50	§ 11,018.50	.54
1906	21,203.82	8,969.90	.42
1907	32,889.00	13,097.44	.40
Total ..	**172,933.72**	‖**91,518.34**	**·53**

* Includes 106·39ozs. dollied. † Includes 428.47 ozs. dollied. ‡ Includes 2.20 ozs. dollied. § Includes .21oz. dollied. ‖ Includes 537.27ozs. dollied.

THE MINES.

Monarch of the East, G.M.L. 137.—This property was abandoned at the time of my visit and the workings could not be inspected. The main line of reef worked is strong and well defined, running through almost the full length of the lease on a bearing practically due north and south and dipping steeply to the west. In addition to this, there is at the north end of the lease a second parallel and much smaller reef a chain or so farther west on which a little work has been done.

Towards the south end of the lease, the main reef cuts out, but another make of stone comes in a chain or so east and runs for a short distance when it also dies out and a third make comes in another chain farther east; this third body of stone continues as a strong reef right through the adjoining lease (Lady of the Lake).

All the quartz bodies are probably formed along one main line of shearing, this being apparently the same as that on which the Weeloona reefs are situated.

The main Monarch reef is said to have been very irregular in size, varying from a few inches up to eight or nine feet: the shoots of gold are also said to have been irregular and small.

Lady of the Lake, G.M.L. 442.—On this lease, which adjoins the Monarch on the south, a good deal of work has been done down to

water level; these workings however were abandoned and were inaccessible. At the time of my visit a little prospecting work was going on along the surface in the hope of picking up a new shoot of gold. The reef is large and well defined, being up to ten and twelve feet in width; the quartz is hard and white and often a good deal laminated.

The gold occurs in small irregular shoots, being usually found on one or other of the walls; these shoots are said to have been very good at the surface but to have cut out at a fairly shallow depth.

Table showing the Yield of the Monarch of the East Leases.

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per Ton.	Total. Ore Crushed.	Total. Gold therefrom.	Average Rate per Ton.
		tons.	ozs.	ozs.	tons.	ozs.	ozs.
1898	Monarch of the East G.M. Co., N.L., G.M.Ls. 137, 442	550.00	287.69	.52			
1899	Do.	1,965.00	1,550.74	.79			
1900	Do.	2,333.00	1,639.42	.70			
1901	Do.	2,762.00	1,799.83	.65			
1902	Do.	2,268.00	1,928.40	.85			
1903	Do.	655.00	691.63	1.06			
1904	Do.	632.00	272.47	.43			
1905	Do.	1,056.00	659.20	.62			
1906	Do.	30.00	58.89	1.96			
					12,251.00	8,888.27	.73
1907	Monarch of the East, G.M.L. 137	..	..	..	222.00	131.71	.59
1907	Lady of the Lake, G.M.L. 933 (late 442)	..	..	..	91.00	108.53	1.19
	Total	..	..	..	12,564.00	9,128.51	.72

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Highland Mary, G.M.L. 674.—This is another abandoned lease, but only a little work has been done on it. There is a very large body of quartz here, the main reef extending through the full length of the lease, and being up to twenty feet in thickness at the surface.

Towards the south end there is a second parallel reef lying a couple of chains to the west. Both these reefs strike slightly west of north, and underlie steeply to the west. They have the usual lenticular character, but not to such a marked extent as some of the reefs. Very little stone has been crushed, and the results were not satisfactory.

This reef is on the same line as the preceding one, and also as the Weeloona.

Up to the end of 1907, the total stone crushed from this lease was 44 tons for 11.53 ounces.

Weeloona, G.M.L. 326.—A lot of work has been done on this ase down to water level, but it is now abandoned, and the workings are inaccessible.

The reef consists of a series of lenticular bodies of quartz varying in length from two to eight chains, and usually separated by a distance of twenty to sixty feet, all occurring within a well defined belt of schist a couple of chains in width. A little south of this lease these quartz bodies die out, but northward they continue in a well-defined line for a distance of over a mile, having a general trend a little north of north-west; in this direction some of them are of considerable length, one on Machine Area 23 reaching over twenty chains in length, and being up to twelve or fifteen feet in thickness at the surface; little or no work has been done on any of them north of the Weeloona.

On the Weeloona the average width of these quartz bodies on the surface is three to four feet, and they have a uniform underlie to the west of 60 to 70 degrees; the footwall as far as could be seen is very clean and regular, but the hanging-wall is not so good; the quartz being clean and white and very hard.

In speaking of this property in 1898, Mr. Blatchford says:—"..... along the 70 feet level the reef varies from 18 inches to three feet in thickness. A large quantity of the quartz, which is

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Note.—The figures given throughout this report have been supplied by the Statist's Branch of the Mines Department and are complete up to the end of 1907.

Owing to the manner in which the returns have been made in past years has been found impossible to obtain the exact returns from individual leases these have frequently been included with those from other leases when they re been the property of the one Company, *e.g.*, the returns from the Dert are given partly under the heading of the lease itself and partly included those of two separate companies owning a large number of leases, it being these latter cases impossible to separate the returns from the different ases; and this occurs in many other cases.

of the white opaque variety, is charged with a dark hard mineral, which, on analysis, proved to be sulph-antimonide of lead and copper, the copper being largely in excess. Carbonate of copper stains are also of common experience."

Table showing the Yield of the Weeloona Lease.

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per ton.
		tons.	ozs.	ozs.
1897	Weeloona, G.M.Ls. 181, 326	..	*15.59	..
1898	Do.	128.00	235.06	1.84
1899	Do.	133.00	206.74	1.55
1904	Do.	364.00	122.22	.34
1905	Do.	235.00	185.17	.79
	Total	**860.00**	**764.78**	**.89**

* Dollied.

Darlington, G.M.L. 875.—This lease is on the north end of the western group or line of reefs, which includes those of the Derwent and Lady Margaretta.

On the north end of the lease is a large quartz reef running north and south, on which a little work has been done; towards the middle of the lease this reef has been faulted, and thrown about five chains to the east by a cross reef striking north-west and south-east, and dipping to the north-east.

The main reef is up to three and four feet in width at the surface, and is of the usual hard white quartz.

This lease has been abandoned for some time, and the workings were inaccessible. The total stone crushed up to the end of 1907 was 40 tons for 43.14 ounces.

Derwent, G.M.L. 149.—Running through this lease and northwards into the Monarch of the East is a large quartz reef striking almost due north and south, and underlying at a steep angle to the west. This reef outcrops continuously over a length of about fifteen chains, and on the surface has an average thickness of four to eight feet. A good deal of work has been done on it down to a depth of about 120 feet, but the workings have been abandoned for some time, and were inaccessible.

In describing these workings, Mr. Blatchford in 1898 states that " . . . . . Along the 50 feet level the reef has an average thickness of eight feet; . . . . . the character of the quartz is white and opaque, being much honey-combed in places; it contains free gold, iron pyrites, and probably some small quantities of copper sulphides."

At the time of my visit a little work was being done near the surface on a small vein of good stone running along the hanging

wall side of the main reef; this vein was from six to eighteen inches in thickness, and was said to be fairly good, but the shoot was of short length, and was nearly worked out.

From what I was able to gather it appears that the original workings were on a similar small vein, and that the shoots of good stone were small, being of no value.

The returns from this lease subsequent to 1899 were included partly in those of the Lake Way Goldfield, 1899, Ltd., and partly in the Gwalia Consolidated, Ltd.

Table showing the Yield of the Derwent Lease.

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per Ton.
		tons.	ozs.	ozs.
1898	Derwent, G.M.L. 149 ..	98.30	223.14	2.27
1899	Do.	66.00	127.83	1.94
	Total	**164.30**	**350.97**	**2.13**

Derwent South and *Lady Margaretta*, G.M.Ls. 378, 375.—On these leases the main line of reefs runs a good deal more west of north than in the Derwent, and on the former very little work has been done, but on the Lady Margaretta (late Gem G.M.L. 469) a good deal appears to have been carried out above water level. Both these leases are at present abandoned, and the workings were inaccessible.

On the Lady Margaretta the reef is of the usual lenticular form, occurring in a well-defined wide belt of schist, the quartz bodies, or lenses, having on the surface a width of from two to four feet.

Table showing the Yield of the Gem Lease (now Lady Margaretta).

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per ton.
		tons.	ozs.	ozs.
1898	Gem, G.M.L. 340 ..	226.55	214.92	.95
1899	Do.	100.00	90.83	.91
1901	Gem, G.M.L. 469 ..	151.00	153.30	1.02
1902	Do.	67.00	52.45	.78
	Total	**544.55**	**511.50**	**.94**

Caledonia, G.M.L. 161.—This lease is situated on the north end of the eastern, or Black Swan group, which includes the reefs of the Dark Horse, Black Swan, Try Again, and Lake Way leases.

The reefs comprising this group, and running through the above and other leases for a total length of over two miles, are not actu-

ally continuous, but consist of a series of lenticular bodies of quartz occurring along the one well-defined shear or fault line; the length of these bodies varies considerably as also does the distance between them; this can best be seen by a reference to the map herewith.

On the Caledonia are two reefs, an eastern, on which all the work has been done, and a western; the former having also been worked on the Dark Horse, the adjoining lease on the south.

The western reef is by far the largest, and outcrops as a continuous body for a distance of over half-a-mile; it is of hard white quartz, and up to twenty or thirty feet in width in places; little or no work has been done on it, and its gold contents appear to be *nil*. The eastern reef is much smaller, averaging in width from two to six feet; the quartz appears to be continuous right through this lease and into the next, having a total length of over twenty chains; the strike of the reef is about 30 degrees west of north, dipping steeply to the west. A good deal of work has been done on this reef, but the old workings have been abandoned, and they were inaccessible.

At the time of my visit a little work was being done near the surface at the north end of the lease, the shoot being said to be small and to be nearly worked out. As far as I could learn all the shoots of gold were small and irregular and did not live down, the bulk of the stone being too poor to pay for working.

The main shaft on this property is down to a vertical depth of 250 feet (?), and at the present time it is being used as a fresh water shaft by the Gwalia Consolidated, Ltd., the supply being fresh and abundant.

In 1898 a return is given of 294 tons of stone crushed, which yielded 296.10 ounces of fine gold, but since that date the returns have been included with the Lake Way Goldfield, 1899, Ltd.

Dark Horse, G.M.L. 169.—Upon this lease a good deal of work has been done on the same body of stone as on the preceding lease, and also on several other reefs farther south along the same line (see map). All the workings, however, are now abandoned, and were inaccessible.

The quartz is of the usual hard white and opaque variety, and on the surface varies from two to six feet in thickness. The gold is said to have occurred in small irregular shoots, and developments were not satisfactory, whilst these shoots appear to have been principally on the footwall side of the reef, as most of the work seems to have been done on this side.

At the present time a little prospecting work is being carried on on the surface near the south end of the lease.

In his report on this property in 1898, Mr. Blatchford states:—"..... On this reef there are two shafts with a vertical depth of 45 and 70 feet respectively. Driving has been done to some extent both north and south along the reef, which varies from two to eight feet in thickness. A water shaft to the west, 65 feet deep, contains good water for drinking and domestic purposes."

Table showing the Yield of the Lake Way Goldfield, 1899, Ltd., Leases.

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per Ton.	Total. Ore Crushed.	Total. Gold therefrom.	Rate per Ton.
		tons.	ozs.	ozs.	tons.	ozs.	ozs.
1897	Dark Horse, G.M.L. 169	10.00	97.88	9.79	274.15	571.24	2.08
1898	Do.	184.15	381.56	2.07	294.00	296.10	1.01
1899	Do.	80.00	91.80	1.15			
1898	Caledonia, G.M.L. 161	..	..	..			
1900	Lake Way Goldfield, 1899, Ltd.. G.M.Ls. 149, 161, 169, 170, 184, 312, 332/3, 358, 378/9, 472/3, 513/4	2,540.00	2,749.64	1.08			
1901	Do.	..	*360.46	..			
1902	Do.	3,422.00	1,475.61	.43			
1903	Do.	213.00	537.26	2.52			
1904	Do.	1,227.00	1,869.87	1.52			
1905	Do.	841.00	967.56	1.15			
1906	.. ..	..	..	..	8,243.00	7,960.40	.96
	Total	..	..	..	8,811.15	8,827.74	1.00

* From Cyanide.

Black Swan Leases, G.M.Ls. 170, 332.—Between these lease
and the Dark Horse there is a considerable break in the line o
quartz bodies occurring over a length of eight to ten chains. O
the black Swan lease (G.M.L. 170) the makes of quartz are not s
continuous as usual, being with the exception of that at the nort
end, only four or five chains in length; they are large, however
often reaching on the surface a thickness of over twelve feet; th
north body has an apparent continuous length of about ten chains
good deal of work has been done on this lease, but the working
re now abandoned, and inaccessible. On the adjoining lease t

the north (G.M.L. 332) a little work is being done near the surface. The gold in this reef has been found principally on the hanging-wall, but the shoots were small and irregular, the bulk of the stone being of no value; in size the reef varies from four to twelve feet, and is of hard white opaque quartz.

Near the south end of the lease a little surface prospecting is being done on another large body of quartz in the hope of picking up a new shoot of gold.

The returns from these leases between the years 1898 and 1906 are included in those of the Gwalia Consolidated, Ltd., and the Lake Way Goldfield, 1899, Ltd.

Table showing the Yield of the Black Swan Leases.

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per Ton.	Total. Ore Crushed.	Total. Gold therefrom.	Rate per Ton.
		tons.	ozs.	ozs.	tons.	ozs.	ozs.
1898	Black Swan, G.M.L. 170 ..	..	..	..	77.00	207.07	2.69
1898	Black Swan North, G.M.L. 332	..	..	..	14.50	22.59	1.56
1906	Gwalia Cons Ltd., Ltd., G.M.L. 170	494.00	425.10	.86			
1907	Do.	435.00	167.31	.38	929.00	592.41	.64
	Total	..	..	..	**1,020.50**	**822.07**	**.80**

Try Again and *Try Again Extended,* G.M.Ls. 677, 945.—These leases are both farther south on the same line as the Black Swan. A good deal has been done on the Try Again, but most of the old workings have been abandoned, and the work at present being carried on is all at, or near, the surface; only a little prospecting is being done on the Try Again Extended.

The reef on these leases consists of the usual series of lenticular quartz bodies, which vary greatly in length and size, some of them being up to 12 feet in thickness.

The shoots of gold appear to have occurred both on the hanging and footwall sides of the main quartz bodies, but, as usual, they are said to have been small and irregular.

Table showing the Yield of the Try Again Lease.

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per ton.
		tons.	ozs.	ozs.
1904	Try Again, G.M.L. 677 ..	310.00	145.70	.47
1905	Do.	244.00	139.76	.57
1906	Do.	275.00	105.05	.38
1907	Do.	245.00	400.52	1.63
	Total	**1,074.00**	**791.03**	**.74**

Lake Way Leases, G.M.Ls. 162, 163.—A reference to the underground plans herewith (Plate I.), will show the amount of work that has been done on this lease. The workings have been abandoned for some time, and were inaccessible, so that an inspection of them could not be made.

The reef is of the usual type, consisting of a series of lenticular quartz bodies of varying length and size; these have in several cases been faulted across, the lines of the faults being clearly seen in the surface workings; these faults are always parallel, and strike slightly east of north, dipping to the west; the displacement of the main line is usually about a chain, and is always to the right; in one or two cases small quartz veins have bee . formed along the lines of fault, which are very local, and do not extend across country for any distance.

On the surface the size of the main bodies of quartz varies from two to eight feet; throughout the workings the reef is said to have been from two to six feet, averaging three or four feet, and on the whole to have been a good deal more regular than is usually the case with the quartz reefs of the district.

Along the bottom level the quartz is said to be going down just as strong as ever, and with every sign of permanency; the values, however, were not very good.

The gold as usual is said to have occurred in irregular shoots, the bulk of the stone being of too low grade to be of any value.

*Table showing the Yield of the * Lake Way Leases.*

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per Ton.	Total		Average rate per ton.
					Gold therefrom.	Ore Crushed.	
		tons.	ozs.	ozs.	tons.	ozs.	ozs.
1898	West Australian Goldfields Ltd., G.M.L. 162	71.00	61.15	.86			
1899	Do.	1,305.00	607.07	.47			
1900	Do.	1,410.00	560.55	.39			
1901	Do.	..	†9.67	..	2,786.00	1,238.44	.45
1906	Lake Way Leases, G.M.La. 162, 163	355.00	215.94	.61			
1907	Do.	275.00	153.66	.56			
					630.00	369.60	.59
	Total	..	..	..	3,416.00	1,608.04	.47

* Between 1901 and 1903, the returns from these leases are included in the Golden Age Consolidated, Ltd.

† From Plates.

The Brothers, G.M.L. 143.—This lease adjoins the Golden Age on the east, the two lines of reef being parallel. As usual, the reef is not continuous but consists of several lenticular bodies of quartz a chain or so apart; the general strike of these is a little north of north-west and they underlie steeply to the west; in thickness varying on the surface from two to ten feet, probably averaging about four or five feet. Even in the apparently continuous bodies of quartz the

The gold as usual is said to have occurred in irregular shoots, the bulk of the stone being of too low grade to be of any value.

*Table showing the Yield of the * Lake Way Leases.*

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per Ton.	Total		Average rate per ton.
					Gold therefrom.	Ore Crushed.	
		tons.	ozs.	ozs.	tons.	ozs.	ozs.
1898	West Australian Goldfields Ltd., G.M.L. 162	71.00	61.15	.86			
1899	Do.	1,305.00	607.07	.47			
1900	Do.	1,410.00	560.55	.39			
1901	Do.	..	†9.67	..			
		355.00	215.94	.61	2,786.00	1,238.44	.45
1906	Lake Way Leases, G.M.Ls. 162, 163	275.00	153.66	.56	630.00	369.60	.59
1907	Do.	..	..	..			
	Total	..	..	..	**3,416.00**	**1,608.04**	**.47**

* Between 1901 and 1903, the returns from these leases are included in the Golden Age Consolidated, Ltd.

† From Plates.

The Brothers, G.M.L. 143.—This lease adjoins the Golden Age on the east, the two lines of reef being parallel. As usual, the reef is not continuous but consists of several lenticular bodies of quartz a chain or so apart; the general strike of these is a little north of north-west and they underlie steeply to the west; in thickness varying on the surface from two to ten feet, probably averaging about four or five feet. Even in the apparently continuous bodies of quartz the

lenticular structure of the reef can be seen as, in an old open cut, overlapping lenses of quartz can be seen separated by a few inches of country. A lot of work has been done on this lease, but it has been abandoned for some time and the workings were inaccessible.

Table showing the Yield of the Brothers Lease.

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per ton.
		tons.	ozs.	ozs.
1898	The Brothers, G.M.L. 143	91.00	109.72	1.21
1899	Do.	167.00	184.74	1.11
1900	Do.	52.00	71.30	1.37
1901	Do.	358.00	281.13	.79
1902	Do.	159.00	89.44	.56
1903	Do.	44.00	55.98	1.27
1904	Do.	762.00	838.50	1.10
1905	Do.	..	..	..
1906	Do.	1,150.00	867.10	.75
1907	Do.	202.00	213.12	1.05
	Total	**2,985.00**	**2,711.03**	**.90**

Golden Age and *Golden Age South*, G.M.Ls. 140, 928.—A lot of work has been done on these properties, more especially on the former, the extent of which may be seen by a reference to the mine plans herewith (Plate II.), whilst on the latter no work has been done below water level.

The workings on the Golden Age have been abandoned for some time past and were inaccessible, so an inspection of them could not be made. The quartz is here more continuous than is usually the case though the lenticular structure is still present. The main line of reef worked extends through the full length of this lease and also, brokenly, through the south lease; its strike is about north-west and it underlie steeply to the south-west. On the surface the quartz frequently reaches as much as 12 feet in thickness and throughout the main workings it is said to have varied from 3 to 13 feet, averaging about 6 feet. The gold is reported to have occurred in irregular patches and not uniformly through the stone, the bulk of which is too poor to be of any value.

On the Golden Age South lease a small party is working near the surface on a small seam of good stone alongside the main reef; no systematic work is being done however.

Just outside the west boundary of these leases is a very large white quartz reef running parallel to the main line; this reef is frequently as much as 20 feet in thickness and in one place rises as a low hill of quartz to a height of 40 or 50 feet; its northern end is only a few chains north of the Golden Age and from this point it runs south-easterly as a practically continuous body of quartz for a distance of slightly over a mile. No work has been done on t[illegible]

northern portion of this reef, and it is here apparently non-auriferous; towards the south end a good deal has been done on it on the Emerald Isle, Republic, and Lady Hopetoun leases (G.M.Ls. 693, 644, 252), more especially on the Republic. All these leases are at present abandoned and the workings could not be inspected.

On the surface the reef is of hard white quartz and varies from four to ten feet in thickness. The workings are all above water level and seem to have been of rather an irregular nature, the gold probably occurring in small shoots which have been "rooted" out and the leases then abandoned. All the reefs occur within well defined belts of schists.

Table showing the Yield of the ‡ Golden Age Leases.

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per ton.	Total. Ore crushed.	Total. Gold therefrom.	Average rate per ton.
		tons.	ozs.	ozs.	tons.	ozs.	ozs.
1898	Golden Age-Lake Way, Ltd., G.M.L. 140	49.00	123.91	2.53			
1899	Do.	1,302.00	903.96	.69			
1900	Do.	9,066.00	4,472.59 *964.76	.60			
1901	Do.	2,482.00	1,003.47	.40	12,899.00	7,468.69	.58
1901	Golden Age Consolidated, Ltd., G.M.Ls. 140, 144, 162/3, 164, 241–243, 318, 380, 422, 441, 477, 494–499, 501, 523, 719, T.A. 9, W.R. 33	922.00	3,611.35	3.92			
1902	Do.	13,479.00	5,304.15	.39			
1903	Do.	19,274.00	6,963.93	.36			
1904	Do.	8,846.00	3,118.42	.35			
1905	Do.	..	†752.60	..	42,521.00	19,750.45	.47
1905	Golden Age, G.M.L. 140 ..	398.00	278.13	.70			
1907	Do.	100.00	26.48	.26	498.00	304.61	.61
	Total	..	..	..	55,918.00	27,523.75	.49

* From plates. † By cyanide. ‡ *See also* Lake Way Leases.

*Table showing the Yield of the *Golden Age South Lease.*

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per ton.
		tons.	ozs.	ozs.
1898	Golden Age South, G.M.L. 139	36.00	5.85	.16
1899	Golden Age South, G.M.L. 380	133.00	270.95	2.04
1905	Golden Age South, G.M.L. 913	78.00	55.13	.71
1906	Do.	495.00	411.60	.83
1907	Golden Age South, G.M.L. 928	479.00	207.57	.43
	Total	**1,221.00**	**951.10**	**.78**

* Between 1899 and 1905 the returns are included in those of the Golden Age Consolidated, Ltd.

Table showing the Yield of the Republic Lease.

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per ton.
		tons.	ozs.	ozs.
1904	Republic, G.M.L. 644 ..	402.00	142.88	.36
1905	Do.	14.00	8.00	.57
	Total	**416.00**	**150.88**	**.36**

Essex, G.M.L. 316.—This is another abandoned lease on which a good deal of work has been done. The reef is of much shorter length than most of the quartz reefs of the district and strikes nearly east and west, underlying very steeply south, being almost vertical in places. It appears to have consisted of a lenticular quartz body some four chains in length which has been formed along a well defined fault line which is traceable in the form of a thin zone of crushed rock for some distance both ways; as seen in the surface workings the size of the main ore body has been on the average from three to four feet.

There is also a second small quartz reef on the north side of the main line, on which a little work has been done. This reef outcrops over a length of about five chains and strikes north and south being approximately at right angles to the main line, by which it appears to have at its south end been deflected to the east.

Table showing the Yield of the Essex Lease.

Year.	Name and Number of Lease	Ore Crushed.	Gold therefrom.	Rate per ton.
		tons.	ozs.	ozs.
1897	Essex, G.M.L. 316 ..	10.00	31.60	3.16
1898	Do.	89.00	134.65	1.51
1899	Do.	223.00	244.07	1.09
1901	Do.	15.00	23.41	1.56
	Total	**337.00**	**433.73**	**1.29**

Lawless, G.M.L. 314.—This is also an old abandoned property. A very large white quartz reef runs through the lease and continues southerly for a total length of about half a mile, outcropping as an almost continuous body of quartz for the whole distance and reaching as much as 20 feet in thickness, probably averaging about six feet. The strike of this reef, which occurs along a well defined belt of schist, is about north-west and south-east and its dip is steeply to the westward.

Lying about a chain to the west of this and within the Lawless lease is a smaller parallel reef on which a little work has been done; this reef outcrops over a length of about eight chains and is from three to four feet in thickness; a little work has been done at the north end of it but this is of no importance.

A fair amount of alluvial (detrital) gold was got over the surface of this lease some years ago, but it has all been worked out and nothing is now being done; the gold was evidently shed from small leaders associated with the big reefs.

Table showing the Yield of the Lawless Lease.

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per ton.
		tons.	ozs.	ozs.
1897	Lawless, G.M.L. 34 ..	10.00	*55.39	5.53
1898	Do.	..	†428.47	
1899	Do.	28.00	11.44	.41
1904	Do.	42.00	7.90	.18
1905	Do.	68.00	9.36	.14
	Total	**148.00**	**‡512.56**	**3.46**

* Include 50.85ozs. dollied. † Dollied. ‡ Includes 479.32ozs. dollied.

All the above leases are working, or have been worked, on quartz reefs. There are several others on which more or less work is being done, but they are not, so far, of much importance.

The following are the principal leases on which "lodes" are being worked:—

Bulletin and *Indicator*, G.M.Ls. 946, 954.—Both of these leases are working on the same line of lode, and the workings on the two properties are connected along the 65 feet level, which is the greatest depth to which any work has been done.

The lode consists of a belt of sheared and shattered greenstone, much foliated in parts, which down as far as opened is very decomposed and weathered; this belt is of very considerable width, being sometimes as much as two chains at the surface and within it are found more or less well defined bodies of ore.

The general trend of the main lode line is about north-east and south-west and its underlie is practically vertical, being if anything steeply to the north-west. It runs from the south boundary of the

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Indicator, through the Bulletin and Bulletin North, junctioning near the north-east corner of this latter lease with a second main lode line running about north-north-west and south-south-east through the Red Page and R.M. leases.

The ore body worked in the Bulletin has an average width of three to four feet and has been opened up for a length of about three hundred feet at the 65 feet level but not much stoping has been done. The main shaft is down about 110 feet and good values are said to have been obtained at this depth; no work, however, has been done, beyond sinking the shaft, below the 65 feet level. There are no defined walls to this ore body, operations simply ceasing at a point when values become too low to pay to work; it consists merely of a narrow zone of crushed rock which has been impregnated with gold-bearing solutions, the impregnation continuing for some little distance into the uncrushed country; the values are naturally highest and most concentrated where the crushing has been greatest.

There seems to be every reason for assuming that there should be other similar ore bodies as these crush lines along the main belt of shearing, and a little crosscutting and systematic prospecting would soon prove whether or not such do occur; so far no work of this description has been done on the Bulletin lease. During 1907, 164 tons from this lease were crushed for a yield of 139.47ozs. of gold, being at the rate of 0.85 oz. per ton.

On the Indicator, the same ore body has been worked and has been opened up for a length of about two hundred feet, also at the 65 feet level but not much stoping has been done; its average width in these workings is slightly less than on the Bulletin, and the gold contents are said to be slightly lower. Only about 20 feet of crosscutting has been done westerly on this lease which is for its full length in foliated (crushed) greenstone, all of which is said to carry a little gold; parts of it where the crushing is more pronounced being stated to be fairly good; no development work has been done at any of these bodies, neither have any crushings been reported.

In its nature the ore is the same in both leases, consisting of very soft decomposed and crushed country rock (greenstone) almost free from quartz and therefore sliming to a very great extent in the battery and making very little sand. Being soft the ore is easily worked and above water it stands fairly well but below water it will, without doubt, require heavy timbering until hard country is met with; down to 110 feet (40 feet below water) there is said to be no apparent change. Once settled country is met with the ore bodies will be found to be more regular and defined, consisting of well marked bands of schist (crushed greenstone); the values will probably decrease slightly below the point to which oxidation has reached, but the channels along which the gold occurs should prove permanent in every sense of the word.

On the Bulletin the water level is about 70 feet and the supply is said to be a good one.

Bulletin North, G.M.L. 959.—Very little work has been done on this lease; the main shaft having been sunk to a depth of about 70 feet and a little irregular stoping carried out at this level. Nothing defined in the way of an ore body has so far been opened up, but the deposit is similar to that in the two preceding leases. The schists here are somewhat harder and more unweathered and the crushing and shearing have not been so regular as in the Bulletin, consequently the ore bodies are more irregular; driving along the strike of the schists, however, would probably overcome this irregularity which appears to be merely local and due to certain portions of the country having resisted crushing to a greater extent than others. A yield of 22.73ozs. was obtained during 1907 from 89 tons crushing, which is at the rate of 0.26oz. to the ton.

Red Page, G.M.L. 967.—A similar class of deposit to that in the Bulletin is being worked on this lease, but only a small party is working on it and not much is being done. The ore body, which runs about north-north-west and south-south-east, dipping steeply to the west, is said to be two feet wide and fairly good. It is exactly similar in its mode of occurrence to the Bulletin ore body, and as it occurs along a well defined belt of schists (shear line) systematic prospecting should be well worth carrying out in the hope of picking up similar parallel bodies.

From this lease, during 1907, 197 tons of ore were crushed for a yield of 228.30ozs., being at the rate of 1.16ozs. to the ton.

Moonlight and *Adelaide,* G.M.Ls. 870, 940.—The same line of lode is being worked on both these leases, but all the developments of any importance have been done on the Moonlight.

The lode line runs on a bearing slightly east of the north-east and west of south-west, turning somewhat more south-westerly on the Adelaide, with an underlie at a fairly steep angle to the northward; it consists of the usual belt of crushed and foliated greenstone schists carrying payable gold values along certain fairly well defined lines.

Running through the middle of the lease at right angles to the lode line, *i.e.,* about north-west and south-east, is a second well defined similar belt of schists (shear line) some two chains or more in width. This is the older and main line and can be followed on the surface for a long distance both northerly and southerly from this point; the lode line cuts right through this belt and it is at, or close to, the intersection that the best values are met with.

Along the lode the gold values occur along the lines of greatest crushing and foliation, certain portions which to a greater extent have resisted crushing being almost barren of gold. The extent of the ore bodies is somewhat irregular as the country on both sides of the main lines have to a certain extent become impregnated, and so also along small irregular fracture lines going off from the main

line. Certain small seams carrying values have also been met with along the line of the older (north-westerly) belt of schist, but these have not been opened up to any extent, as practically all the work has been on the other line.

The lode has been opened up at the 70 feet level for a total length of about 350 feet and a little crosscutting has been done, but very little stoping. Work is at present being carried out at the west end at the 70 feet level where the ore body has a maximum width of about ten feet but it is not well defined, and the values are somewhat erratic. This body consists of a zone of rock which has been considerably more crushed and fractured than the enclosing portions, thus having given freer access to gold-bearing solutions. Other similar ore bodies are known to occur throughout the workings but not much has been done on them. The whole of the country within the shear zone, probably as much as two chains in width, carries a little gold but not enough to be payable. Owing to the irregular occurrence of the payable ore bodies the whole deposit needs very careful prospecting and sampling to enable its true value to be determined. The irregularity of the ore bodies will probably cease when settled country is met with as the crushed zones along which they occur will then be better defined and there will not be so much impregnation of the enclosing rock. Just at the intersection of the two main lines of shearing there will however always be a certain amount of irregularity in the occurrence of the ore bodies owing to the broken nature of the country at this point.

So far throughout the workings both the ore and the "country" are very soft and rotten, work being easy on this account, but the country, although standing pretty well above water level, will probably require extensive timbering below. The ore is almost free from quartz and slimes largely during battery treatment.

Small patches or pockets of massive stibnite (sulphide of antimony) are occasionally met with in the workings on this lease, which are small, rarely exceeding a few feet in length, and a foot or so in thickness and can readily be separated from the rest of the ore. These pockets are said to be high in gold values, but so far no effort has been made to treat them.

On the Adelaide, which joins the Moonlight on the south-west, a little work has been done along the same line of lode. The ore bodies here have the same characteristics, being merely narrow zones of more highly crushed rock which have become impregnated with gold.

The workings are only down about 60 feet, and about 100 feet of driving has been done, but no stoping and no crushing have been made to date. No crosscutting has been done, which is absolutely necessary to prove the existence, or otherwise, of parallel ore bodies such as are likely to occur in a deposit of this nature.

Table showing the Yield of the Moonlight Lease.

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per ton.
		tons.	ozs.	ozs.
1905	Moonlight, G.M.L. 870 ..	212.00	95.37	.45
1906	Do.	436.00	156.07	.36
1907	Do.	707.00	351.76	.50
	Total	**1,355.00**	**603.20**	**.45**

Mother of Gwalia, G.M.L. 953.—This lease is situated on the east side of the Adelaide, and on it a little work has been done on a couple of small parallel lode lines running north and south-east; these have been opened up over a width of two or three feet, but no work of any importance has been done on them. A lot of massive stibnite occurs on both lines, and it is apparently this that has been worked as it is said to be highly auriferous.

Gwalia Consolidated, Ltd., G.M.Ls. 149, etc.—A reference to the underground plans herewith (Plate III.) will show the amount of work that has been done on this property.

The lode is similar in nature to that in the Moonlight and Bulletin leases, consisting of a wide belt of crushed and shattered rock carrying in parts payable gold values. It runs almost due north and south, and is very persistent in strike; owing, however, to the *débris* and recent deposits which cover the ground to the northward, it is difficult to trace the line on the surface in this direction, but it probably follows a course as shown on the map. About the centre of the property the main lode appears to be faulted by a large "buck" quartz reef, which runs about north-west and south-east, and can be followed on the surface for a considerable distance (*see* plan). The two portions of the lode to the north and south of this reef are known as the "north" and "south" lodes respectively.

Most of the work has been done on the north lode, which appears to consist of two main crush, or shear, lines separated by about 50 feet of more or less shattered and crushed country rock; these two main lines consist of bands of highly foliated rock, which, owing to their foliation, have given freer access to gold-bearing solutions. Their width varies a good deal, the eastern one, on which most development has been done, having been worked over an average width of about 15 feet, while the western one is a good deal smaller.

As above stated, the country between these two bodies is more or less crushed and shattered (greenstone), and along the fracture lines gold-bearing solutions have had access, and have impregnated it for some distance on either side. Where these cracks and cleavages are most numerous the impregnation has of course been greatest, and the gold values have risen sufficiently high to enable much of the country to be classed as ore. At the north end this impregnation

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has been so uniform that the whole of the country between the two main lines (60 feet) has been stoped, and so also at the surface of both the north and south where the whole formation has been mined by means of a large open-cut 60 to 70 feet in width.

Even the main ore bodies are irregular, as they have no defined walls, and there are continually small spurs, or makes, of ore, going off from them; the values also vary a good deal even along the main lines according to the amount of foliation and crushing that has taken place.

On the south lode not so much work has been done as on the northern one, although the deposit here is just as large and, if anything, more irregular, the main line being less defined.

At a depth, when more settled country is met with, the great size and irregularity of these ore bodies will probably decrease, and they will develop into certain well-defined belts of schist (crushed greenstone), along which the gold values will be found. The enclosing country, always more or less shattered, will probably be found to be barren of gold except immediately along small fracture lines.

Although this property has been worked some six or seven years, nothing has been done below the 100 feet level, beyond sinking the main shaft to a depth of about 200 feet, and there is still a very large amount of ore in sight above this; most of the ore milled has been taken from several huge open-cuts carried down to 50 or 60 feet from the surface for a width varying from 20 to 60 feet.

At the north end of the leases a little massive stibnite is found in the lode line; this is in well-defined patches, and does not, as a rule, occur in small quantities throughout the ore, and so does not interfere to any extent in the treatment.

The mine is situated on low-lying country near Lake Violet (Lake Way), and the original water level was about 30 feet, the supply being salt and unlimited.

Table showing the Yield of the Gwalia Consolidated, Ltd.

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per ton.
		tons.	ozs.	ozs.
1902	Gwalia Consolidated, Ltd., G.M.Ls. 149, 170, 316, 516, 524, 540/2, 545/9, 550/1, 569, 906, 930/1, 937, 943/4, 952	11,074.00	4,710.97	.43
1903	Do.	3,843.00	1,562.63	.41
1904	Do.	..	* 3,624.64	..
1905	Do.	16,577.50	6,770.90	.41
1906	Do.	16,278.82	5,330.07	.33
1907	Do.	28,859.00	10,675.90	.37
	Total	**76,632.32**	**32,675.11**	**.43**

* By Cyanide

Wiluna Queen, G.M.L. 961.—This lease is situated at the extreme south end of the district close to the edge of Lake Violet (Lake Way). A little work has been done on a narrow belt of schist running about north and south, which has been opened up to a depth of about 20 feet, but nothing further has been done. There are three or four feet of lode matter exposed, but the values are said to be very low. The developments up to the present have not been of a very important nature.

Table showing the Yield from Leases at Wiluna, other than those already given, up to the end of 1907.

Year.	Name and Number of Lease.	Ore Crushed.	Gold therefrom.	Rate per ton.
		tons.	ozs.	ozs.
1907	Big Lode, G.M.L. 976 ..	27.00	9.40	.35
1901	Bonanza, G.M.L. 507 ..	13.00	4.73	.36
1904	Brothers South, G.M.L. 704	54.00	15.03	.28
1904	Clear View, G.M.L. 751	60.00	7.17	.12
1902	Cygnet, G.M.L. 536 ..	79.00	31.35	.40
1907	Dudley Castle, G.M.L. 970	27.50	1.93	.07
1899	Ethelstone, G.M.L. 312 ..	18.00	8.14	.45
1898/9	Federal, G.M.L. 153 ..	135.00	73.55	.55
1904	Federal, G.M.L. 631 ..	166.00	65.68	.39
1901	Fixed Deposit, G.M.L. 531	12.00	8.38	.70
1897	Golden Age North, No. 1 G.M.L. 311	10.00	96.24	9.62
1904	Great Wonder, G.M.L. 740	215.00	89.86	.42
1898	Inverness, G.M.L. 227 ..	37.75	5.16	.14
1906	Kingfisher, G.M.L. 920 ..	49.00	16.85	.34
1904/6	Lady Wiluna, G.M.L. 837	..	*212.94	..
1905/6	Lake View, G.M.L. 905	322.00	93.40	.29
1898	Lake Way Consols, G.M.L. 335	38.00	26.11	.69
1898/9	Lake Way Consols Extended, G.M.L. 342	77.00	116.16	1.51
1902	Lake Way Extended, G.M.L. 589	100.00	104.49	1.05
1898/9	Lake Way Queen, G.M.L. 237	58.00	48.12	.83
1900	Little Wonder, G.M.L. 413	30.00	15.51	.51
1907	Lone Hand, G.M.L. 956	80.50	17.96	.22
1904	Margaret Ewen, G.M.L. 708	140.00	68.10	.49
1905	Margaret Ewen, G.M.L. 871	189.00	114.13	.60
1899	Monarch and Derwent United, G.M.L. 333	10.00	2.95	.29
1898/9	Monarch North, G.M.L. 328	69.00	18.59	.27
1904/6	Moonlight North, G.M.L. 798	597.00	216.30	.36
1900	Off Chance, G.M.L. 403	37.00	16.12	.44
1898	Queen of Lake Way, G.M.L. 157	50.00	21.34	.43
1906/7	Squib, G.M.L. 917 ..	131.00	30.50	.23
1907	White Swan, G.M.L. 980	28.00	7.61	.27
1907	Wild Duck, G.M.L. 990	18.00	8.84	.49
1904/5	Wiluna Star, G.M.L. 730	440.00	205.40	.47
1906	Woodcutter, G.M.L. 911	30.00	17.03	.57
	Sundry Claims ..	1,585.15	912.10	.58
	Total	4,932.90	2,707.17	.54

* By Cyanide.

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GOVERNMENT ASSAYS.

Assays, Analyses, and Determinations of any Western Australian Ore or Rock will be made by the Assayer to the Geological Survey, **when not unduly interfering with official work**, subject to the following conditions:—

1. Each sample must weigh at least 6oz., but not more than 2lbs.
2. Each sample must be enclosed in a separate canvas bag or strong paper wrapper, with a slip of paper bearing the name and address of the sender, together with a private mark by which it may be readily identified.
3. The parcel must be forwarded, **prepaid**, to:—

   The Government Geologist,
   Geological Survey Office,
   Perth.

4. A letter must be sent at the same time to the same address, stating for what metals the samples are to be assayed, or containing other instructions, as the case may be.

(N.B.—It is always advisable to keep duplicate samples of those submitted.)

5. Before any assay is made the prescribed fee must be paid to the Mineralogist and Assayer, or sufficient reasons, in accordance with Section 7 below, be furnished for having the samples treated free of cost.

6. The following fees will be charged:—

	£	s.	d.
(a.) Determination of a Rock or Mineral	0	10	6
(b.) Assay for Lead, Iron, or Manganese, each ..	0	10	6
(c.) Assay for Silver, Copper, or Tin, each ..	0	12	6
(d.) Assay for Gold or Zinc, each	0	15	0
(e.) Dry Assay for Lead, Silver, and Gold ..	1	1	0
(f.) Assay for Antimony, Bismuth, Chromium, Cobalt, Mercury, or Nickel, each	1	11	6
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(h.) Complete Chemical Analysis of any Mineral or Ore, according to number and nature of determinations .. .. £2 12s. 6d. to	5	5	0
(i.) Other determinations, according to time spent, up to	2	12	6

A reduction of 20 per cent. on the above amounts will be made in favour of any person submitting, in one parcel, five or more samples for identical treatment.

7. With the object of encouraging bonâ fide prospecting, free Assays will be made under the following circumstances:—

(a.) The sample must have been obtained from land within the State not held under lease for mining purposes.
(b.) The exact locality where the sample was found must be disclosed.
(c.) The sample must be of sufficient promise to warrant an assay being made at the expense of the State.
(d.) Free Assays will not be made of samples showing free gold, or of tailings or other metallurgical products, or of umpire samples.

8. The Department reserves to itself the right of refusing to make any particular Assay, and also the right of publishing at any time the results of an Assay made at the public expense.

A. GIBB MAITLAND,
Government Geologist.

By Authority: Fred. Wm. Simpson Government Printer, Perth.

WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 35.

GEOLOGICAL REPORT

UPON THE

GOLD & COPPER DEPOSITS

OF THE

PHILLIPS RIVER GOLDFIELD.

BY

HARRY P. WOODWARD,
Assistant Government Geologist.

WITH WHICH IS INCORPORATED A

Description of the Crystalline Rocks of the District,

BY

E. S. SIMPSON and L. GLAUERT.

Issued under the authority of the Hon. H. Gregory, M.L.A., Minister for Mines.

WITH TWO MAPS, EIGHT PLATES, AND SEVEN PHOTOGRAPHS.

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BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.

1909.

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I.—MAPS.

Geological Map of Northampton: by A. Gibb Maitland. Scale, 20 chains per inch. Two sheets. Price, 2s. 6d. **1898.**

Geological Map of Coolgardie: by T. Blatchford and E. L. Allhusen. Scale, 16 chains per inch. Four sheets. Price, 10s. **1898.**

Topographical Map of Kalgoorlie: by W. D. Campbell and S. J. Becher. Scale, 10 chains per inch. Four sheets. Price, 5s. **1900.**

Mining Map of the Boulder Belt: by W. D. Campbell. Scale, 4 chains per inch. Two sheets. Price, 5s. **1900.**

Geological Map of the North Lead, Kanowna: by Torrington Blatchford. Scale, 8 chains per inch. Price, 1s. **1901.**

Geological Map of Kalgoorlie: by A. Gibb Maitland and W. D. Campbell. Scale, 10 chains per inch. Six sheets. Price, 21s. **1902.**

Geological Map of the Boulder Belt and Sheet of Horizontal Sections: by A. Gibb Maitland and W. D. Campbell. Scale, 4 chains per inch. Three sheets. Price, 12s. 6d. **1903.**

In preparation:

Geological Sketch Map of Western Australia: by A. Gibb Maitland. Scale, 1/1,584,000. Four sheets.

II.—REPORTS.

Reports by the Government Geologist in connection with the Water Supply of the Goldfields, containing—(*a.*) Coolgardie and Kalgoorlie; (*b.*) Menzies; (*c.*) Cue. Price, 1s. **1897.**

Annual Progress Report for the Year 1897. (*Out of print.*) **1898.**

Annual Progress Report for the Year 1898, containing—

[illegible] 1899.

[illegible]

Preston [illegible]
Prospects of the Greenbushes [illegible]
North Lead, Kanowna; Bulong Deep Leads; [illegible]
Alluvial Deposits, Donnybrook Goldfield; Subsidy to the Norseman Gold Mines, Ltd.; Gascoyne District; Extension of Artesian Water-carrying Strata from South Australia. Price, 1s. **1901.**

1909.

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1909.

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PREFATORY NOTE.

The work of examining the Ravensthorpe District of the Phillips River Goldfield was commenced in the middle of the year 1907 by Mr. H. W. B. Talbot, Topographical Surveyor to the Department, who spent several months upon the construction of a feature map upon which contour lines were accurately laid down at intervals of ten feet.

In April of the present year I commenced the Geological examination, but owing to the absence of the Government Geologist, was unable to devote my whole time to it, therefore the mapping of the rock formation was carried out by Mr. Talbot under my supervision and it is only just that I should here pay him the tribute by stating that this work was done in a highly satisfactory manner.

From a geological point of view this district is the most complicated yet examined in this State, and in consequence of exceptional interest, the only point for regret being that these formations could not be observed in their unaltered condition owing to the fact that in only one or two instances have they been penetrated below the ground water level (30 to 100 feet), whilst the deepest mine is only 400 feet and still in the fracture zone.

The report has been divided into three sections, the first consisting of the Geology, etc., from a field point of observation, the second section of the laboratory notes upon the rocks by Messrs. Simpson and Glauert, whilst the third is devoted exclusively to a description of the mines examined upon this and previous occasions. The whole is accompanied by a geological map in two sections, one embracing the western area which includes the Ravensthorpe Mining Centre proper, whilst the other or eastern takes in those of Mt. Desmond and Kundip.

The preparation of a report upon an area that has previously been described by other qualified men is always a difficult and unpleasant duty, for at the best of times opinions must differ, whilst in so complicated a district as Ravensthorpe these are apt to do so more widely; but since both Messrs. Montgomery and Blatchford in putting forward their views, have stated that these were only provisional owing to the lack of a detailed geological map, I feel sure that they will not look upon these points of difference as in any way antagonistic or critical but simply as conclusions arrived at from my own observations under more favourable conditions than they experienced.

HARRY P. WOODWARD,
Acting Government Geologist.

30th November, 1908.

PART I.—Introduction.

This Goldfield, which was originally proclaimed in 1900, is situated upon the Southern Coast, its port of Hopetoun being about 150 miles to the eastward of Albany from which there is a weekly mail boat service.

Hopetoun is now connected with Ravensthorpe, the official centre, by a Railway line about 40 miles in length which also serves the mining centres of Kundip and Mt. Desmond.

The portion of this field which has been geologically mapped embraces the whole of the known mining area with the exception of the small centre of West River and Mt. Purchas, which were not considered to be of sufficient importance to be included, since the work entailed would have been very considerable. The area covered by the geological map is about 85 square miles, the whole of which has been also topographically surveyed and contour lines accurately laid down at 10 feet intervals of elevation above the sea level.

The following table gives the rainfall returns as supplied by the Commonwealth Meteorologist:—

	Ravensthorpe	Hopetoun
1902	17.07 ..	18.86
1903	13.60 ..	17.93
1904	19.49 ..	28.20
1905	14.90 ..	17.84
1906	14.78 ..	19.90
1907	11.84 ..	16.07
Mean of 6 years ..	15.28 ..	19.80

PHYSICAL FEATURES.

The main and most striking feature of this district is the Ravensthorpe Range which is visible from the coast; it starts at its southern end upon the eastern side of the township of Kundip, and runs in a generally north-westerly direction for a distance of about nine miles, presenting a bold steep escarpment to the south-west, whilst upon the north-east it is not so precipitous, neither does it present so range-like an appearance since the adjoining plains upon this side are more elevated. It has been described as a horseshoe-shaped range sweeping round from a north-westerly course to a more westerly one, but more correctly speaking it consists of two sections, the southern of which strikes west of north and the northern north of west, whilst between the two a sharp line

of dislocation has taken place at which point it has been cut through by the Cordingup Creek, which flows to the eastward in a steep gorge-like valley. In its southern section the two highest peaks are Mt. Desmond and Mt. Decker which attain an elevation of 1,150 and 1,050 feet respectively, both being conspicuous land marks since they dominate considerably the remainder of the Range.

In the northern section the Range takes a sharp turn and runs upon a more westerly course but although its height is generally greater than the southern portion and it attains an elevation of 1,200 feet above the sea level, it is not so imposing owing to the fact that there are no very conspicuous peaks and the country immediately to the southward is more hilly.

From the first mentioned section in the vicinity of Mt. Desmond a high ridge runs from it in a westerly direction, then sweeping round to the northward rejoins the range in its northern section at a point north of the Floater mine. This ridge forms a basin with the Ravensthorpe Range and divides the watersheds of the Jerdacuttup and its tributaries, which flow to the eastward from the Steere and Phillips Rivers, which flow to the south and west.

This basin-like area is drained by the Cordingup Creek and its principal tributary, the Cattlin Creek, which flow over large and rich alluvial flats uniting near the site of the old smelting works below which the combined streams flow in a gorge-like channel through the Range in an easterly direction, upon the north-eastern side of which it junctions with the Jerdacuttup River.

The western area of this map is drained by the Annabelle and Stevenson Creeks, which flow in a southerly direction, and the south-western portion by the Manyutup Creek flowing in a westerly direction, all of which are tributaries of the Phillips River.

The district between Mt. Desmond and Kundip is drained by the Steere and Western Steere Rivers, the former of which rises near the Elverdton mine and flows in a southerly direction along the foot of the Ravensthorpe Range, being fed by numerous water courses which join it both from the east and west.

The Western Steere rises to the south-west of the Elverdton mine and follows a course approximately parallel with the Steere River, with which it unites to the southward of the area covered by the map.

Between the Cordingup and the Cattlin Creeks there are some extensive and rich alluvial flats covered with gum trees of considerable size, but elsewhere the country is rough or undulating, being broken by numerous gullies.

With the exception of the granite and elevated sand plain areas, which are only covered by low stunted vegetation, the ridges and gullies are densely covered with mallee intertwined with creepers, which are a great hindrance to a person walking off the tracks. The soil of the large flat, as well as the greenstone area in the north-western section of the map, is a rich red or dark brown

Photo. H. W. B. Talbot. Neg. 413.

The Ravensthorpe Range, with Mt. Chester tunnel.

clay admirably suitable for wheat-growing, whilst the granite area, with the exception of some dark and light clay patches, is of a poor sandy character similar to that of the elevated sand plains.

The underground water supply has proved to be plentiful, but invariably salt or slightly brackish at best, the latter being generally of an alkaline nature and met with in the granite area.

GEOLOGY.

A transient glance at the geologically coloured map will at once convey to the observer the intricate character of the dyke system and the variety of rocks exposed at the surface within this limited area, but only a slight idea of the complex character presented by the crystalline series in this district can be formed even when it is stated that these belts and patches of colour with one symbol as representative of one class of rocks are in reality very often further intersected by numerous minor dykes or veins of too small a size or of too great a similarity in their weathered state to be mapped in.

Besides the complex of crystalline rocks exposed, a further series of what may possibly be old and highly metamorphic sedimentary are also represented followed in ascending order by a more modern although probably fairly ancient series of sandstones, quartzites, and conglomerates, whilst further to complicate matters considerable tracts of the surface are covered by superficial deposits of clay or sand which for the most part effectually conceal the nature of the underlying rocks, although the general character of these may often be approximately arrived at by examining the composition of the weathered superincumbent material.

No geological age can be assigned to any one of the formations or groups of rocks in this district owing to the fact that organic remains by which such points are determined have not as yet been discovered, whilst should fossils be discovered in the sandstone series (which is the only possible one) no great advances in this direction will be made, since these beds are the most modern in the area.

Generally speaking, the north-western section or greenstone area is covered with clay, therefore no rocks are visible, their character being determined by the nature of the soil and work done by prospectors; in the central section however, the rocks outcrop in a practically unaltered condition and although of considerable complexity they are most easily determined and mapped in. In the range sections upon the other hand the whole series, although outcropping, is so highly altered even to depths of close upon 100 feet that it is quite impossible to determine with accuracy their true character, they are further complicated by a series of parallel interfoliated ferruginous lode-like bodies of a lateritic character.

In the following description these rocks have been divided into groups, the first, probably the oldest constituting

Ravensthorpe Range, after which the series is called, consist of weathered basic schists and serpentines, the former of which are intersected by numerous parallel ferruginous bodies and ferruginous banded quartzite reefs and often capped by laterite whilst the latter is usually covered by a superficial deposit of magnesite.

The second series are the granites with their intersecting dykes of diabase, diorite, quartz diorite and kersantite, in the schistose portion of which many of the copper dykes are situated, whilst others lie at its contact with the greenstones.

The greenstone series next being apparently the magnetic nucleus from which the basic dykes referred to above radiated into the granite. This series is intersected by pegmatite, felsite, quartz diorite, and camptonite dykes. Following in ascending order are the Kundip series of sandstones, which must have at one time covered a considerable portion of this area, since small outliers and detrital material occur at places all over it. They are of interest in so far that they are the only distinctly stratified rocks of the district.

The superficial, travertine, laterites, and alluvium are of little interest but the lodes which are treated separately are extremely so, the great drawback being the very limited extent of the workings, particularly in depth, which precludes the possibility of so thorough an investigation into their character as could be desired.

Ravensthorpe Range Series.—Probably the oldest series of rocks in this district are the highly weathered and altered schists which form the Ravensthorpe Range, but notwithstanding the fact that they rise to a considerable elevation and have been cut through by the Cordingup Creek, at no point are they exposed in an unaltered state.

These rocks at their outcrop are of a light brownish colour and consist of kaolin, silica, and iron, the latter being in the form of limonite (hydrated oxide of iron); they have a marked lamination which runs in a north-westerly direction identical with that of the Range and are traversed by numerous parallel lode-like bodies of iron ore and a series of banded quartzite veins of considerable size and great longitudinal extent.

These ironstone bodies have been quarried at one or two points for flux for the local smelters, but so far as tested they have proved to be of a comparatively superficial character; a shaft at the Iron Knob sunk to a depth of about 70 feet did not pass through anything but kaolinised rock containing small veins of oxide of iron. At one or two points copper stains have been observed, but so far no appreciable quantity of the ores of this metal; their occurrence has, however, been interpreted as indicating that these ferruginous bodies are the gossans or iron caps of copper lodes.

Upon a lease called the Mt. Chester, situated close to Mt. Desmond, one of these bodies is replaced for a length of about 250 yards by a manganese (pyrolusite and psilomelane) lode which at a

Photo. H. W. B. Talbot. Neg. 415.

The Iron Knob
(Ironstone flux quarry.)

point where it was cross-cut at the surface measured 20 feet in width.

With the object of testing this lode at a depth an adit level was driven for a distance of 424 feet into the steep hill face 90 feet below the outcrop. This is of considerable interest since it is one of the few points at which this series may be examined, otherwise than at the surface. The rocks in this drive present a well-marked schistose structure, the strike of the folii being north-westerly with an inclination of from 70 to 75 degrees to the south-westward. They are mostly white, light yellow or grey in colour and highly kaolinized but less hard than at their outcrop since the cementing oxide of iron is absent, it having segregated into the leaching channels.

A specimen [**7828**] from this drive exhibits a banded structure which varies in colour from grey to yellowish white, the whole being pitted by small cavities representing casts of marcasite (white iron pyrites) all trace of which mineral has been entirely removed.

In this drive no ferruginous body of any size was cut notwithstanding the fact that between its mouth and the manganese lode outcrop at the surface a large one is exposed; this appears to be conclusive evidence that they are of no vertical extent.

The Mt. Decker tunnel which is close by is also of interest, but not nearly so much since it has been driven in the direction of the rock laminations, therefore little variation in its character occurs; neither does it throw any light upon the nature of the ferruginous bodies.

At the southern end of this belt of rocks a considerable amount of work has been done upon them in the Gem and Two Boys leases, but owing to the nearly horizontal lie of the formations, only a moderate vertical depth has been attained, therefore those encountered are still of a highly altered character, being white and almost pure kaolin near the surface, whilst at the lowest levels they pass into undoubted greenstone schist in a very much weathered condition.

Owing to the elevated position occupied by this apparently old land surface the changes wrought by oxidation, hydration, and subsequent leaching upon this series, which have extended over a considerable period of geological time, have so completely altered their character to a greater depth than at present explored that it is impossible to state with any degree of confidence what their origin may have been, both Mr. Montgomery and Mr. Blatchford lean towards the metamorphic sedimentary theory; whilst the former authority has made further the suggestion that the ironstone gossan-like bodies may possibly be the caps of interbedded cupriferous lodes.

If this sedimentary origin theory is the correct one these rocks must, previous to their leaching, have been altered by heat into

greenstone, in which case during this metamorphism the iron in the form of pyrites must have segregated to a very considerable extent into parallel belts or zones following the induced foliation which may or may not have been in uniformity with the original bedding.

A careful examination however, made under more favourable conditions than were possible for former observers, leads to the conclusion that the rocks comprising this range are of igneous origin and are of a similar greenstone type to those met with upon the goldfields generally. This is further supported by the occurrence of a belt of magnesite capped serpentine in the centre of and following the same direction as the range, which rock from its petrological character is clearly an alteration of the hornblende series.

The parallel ferruginous bodies which intersect this entire series with the exception of the serpentine have in no instance exhibited any of the recognised characteristics of fissure lodes, for neither do they possess the marked definition usually noticeable between lode formation and country rock nor, so far as tested, have they proved to be of any vertical extent. In composition at the surface they are identical with the laterite deposits which cover and cap a considerable extent of these ranges and in consequence they are most probably of similar origin, their parallel character and continuity being due either to the superior capillarity of certain belts of schists which have allowed of the ascension of ferrous solution or to the fact that a series of highly basic ferro-magnesian dykes have been intruded along the foliation planes of the primary greenstone schists, whilst the weathering of their outcrops has yielded belts of highly ferruginous laterite.

In support of the basic dyke theory, a reference to the map will at once demonstrate the fact that the course assumed by these parallel ferruginous bodies is in general uniformity with that of the basic dykes in the granite area which lies immediately to the westward, certain irregularity in these latter being due to the character of the rocks since in a schistose series it is only natural that dykes should assume a greater degree of parallelism in conformity with the foliation than in a more massive crystalline rock-like granite.

The conclusion arrived at is that these ferruginous bodies are not lodes but simply laterite cappings which follow the outcrop of a series of ferro-magnesian dykes whilst the enclosing rocks or country are altered greenstone schists of probable igneous origin.

Besides the ferruginous dykes referred to above there are a series of banded ferruginous quartzites (jasper in part) identical with those met with upon the Eastern Goldfields. These are of even greater longitudinal extent than the more basic series and are apparently of very considerable antiquity since the boulder and pebble conglomerate beds met with near Kundip are very largely composed of them.

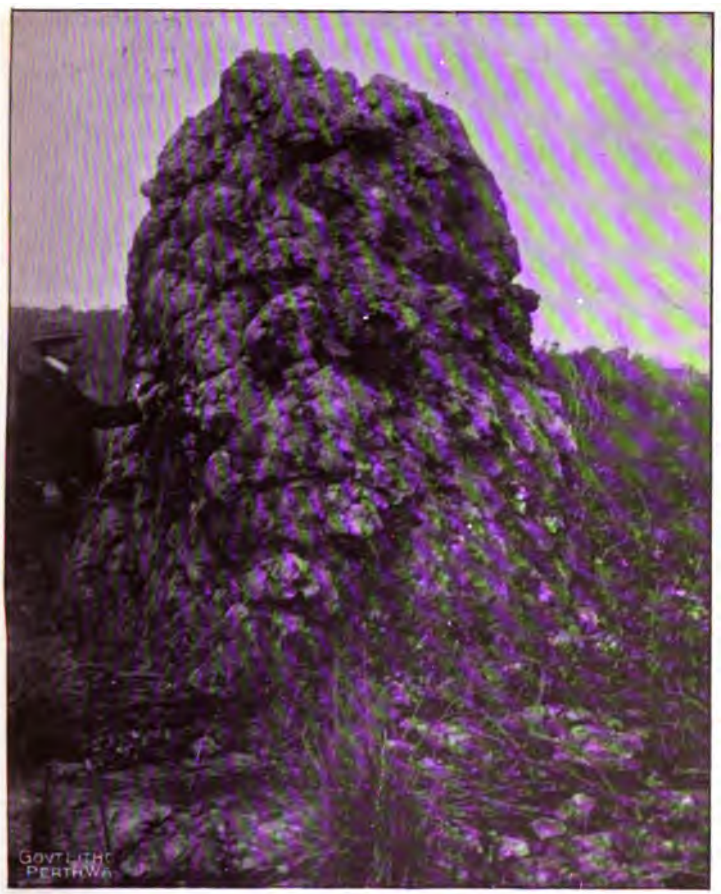

Photo. H. W. B. Talbot. Neg. 414.

Showing peculiar weathering of Banded Quartzite.

They in all probability represent shearing lines since they have a course parallel to that of the foliation of the schists the banded structure being due to the gradual deposition from ascending mineral solutions as the fissure slowly opened owing to the contraction of the rocks in the process of cooling, the layers of differing material being due to varying composition of the depositing solutions over a long period. Up to the present bodies of this character have nowhere proved to be of any direct economic value in this State but that they have played a hand in the deposition of gold is proved by the fact that where they have intersected auriferous veins the latter are of much greater value in their immediate proximity.

The whole of the area occupied by these rocks is densely covered with scrubby vegetation, whilst considerable tracts upon the elevated portions are capped by sheets of laterite.

The Granitic Series.—Under this heading are included the intrusive granites and intersecting basic dykes which occupy a central and southern portion of the area covered by the map between the Range and the township and to the southward of the latter. They are in all probability a portion of the series met with upon the southern coast which extend from the Warren River upon the west to Israelite Bay upon the east.

These rocks for the most part outcrop at the surface in a practically unweathered condition, therefore owing to the scarcity of soil only scant herbage of a hard scrubby nature is able to exist and in consequence their mapping is made exceedingly easy. At one or two points however the decomposition of this rock has yielded a white or dark grey clay upon the latter of which timber of considerable size or patches of dense mallee often flourish.

Extensive tracts of superficial deposits of sand are also met with in places which completely mask the character of the underlying rocks, but from the nature of these deposits it may be inferred that they were primarily derived from the weathering of the granites although possibly at a subsequent period they formed the sandstones of the Kundip series.

There are also considerable tracts of alluvium which are particularly well developed in the basin-like area drained by the Cordingup Creek, which were originally covered by fine salmon gum timber, but this has to a very great extent now been cut down either for mining purposes, for fuel requirements, or with the object of clearing the land for farming since the soil is of a very high quality.

These granites belong to the soda-lime felspar group, and vary very considerably in character and composition from fine-grained compact rocks to very coarsely crystalline ones whilst they sometimes contain considerable quantities of hornblende, particularly when in the proximity of basic dykes.

The whole of this area has been shattered by the basic intrusions to the north-west from which magma numerous greenstone

dykes and masses diverge intersecting the granites in a general south-easterly direction with a degree of parallelism that is remarkable.

These dykes consist for the most part of diorite or amphibolite possibly resulting from the alteration of diabase, which rock is exposed at one or two points in the form of dykes having an east and west or north-easterly course cutting through the normal greenstones and therefore of probably more recent origin. Besides the diabase there are a series of large quartz diorite dykes which break through all the others in a north-easterly direction; these, near the Elverdton mine and to the southward of it, are well developed and of very considerable size, whilst this class of rock is only represented by one or two quite small dykes in the Ravensthorpe section of the map.

Besides the dykes which attain sufficient dimensions to be mapped in there are belts of country particularly in the contact zone, in which the basic veins are so small and so numerous that in some cases hand specimens exhibit these whilst further the majority of the copper lodes are also greenstone dykes situated at or near the contact, but these will be more fully described later on.

Fringing the eastern edge of this area and abutting on to the southern section of the range, in the locality of the Elverdton mine, is a belt of schistose granite, the foliation of which follows the prevailing northerly trend, and this class of rock contains some of the best defined and richest cupriferous dykes of the district.

In the granite area the basic dykes are very easily traced by the character of the vegetation, the rich red soil derived from the weathering of the latter, supporting a much more luxurious growth than the poor sandy soil of the granite area. In other places where less weathered rocks are met with at the surface, the dyke appears like dark bands which can be traced without any difficulty. At one or two places there are what appear to be fault lines crossing the dykes; if this is the case the displacement must have been very considerable, in fact rather too much so, to be a fact, therefore, the more probable solution of this phenomenon is that the dyke fissures have suddenly terminated abruptly upon shearing planes. There is very little doubt but that considerable faulting has taken place, an instance of which, on a minor scale,, is visible in the Elverdton mine, whilst the gap in the range, through which the Cordingup creek flows, is also one of them upon a larger scale.

The Greenstone Series.—This series of rocks occupies the extreme north-western portion of the area geologically mapped, beyond which they extend according to Mr. Blatchford in a comparatively narrow belt for a distance of about 12 miles in the direction of Cocanarup.

Most of this greenstone area is covered with a layer of from two to six feet in thickness of red loam or clay, which completely masks the character of the rocks, therefore, with the exception of those

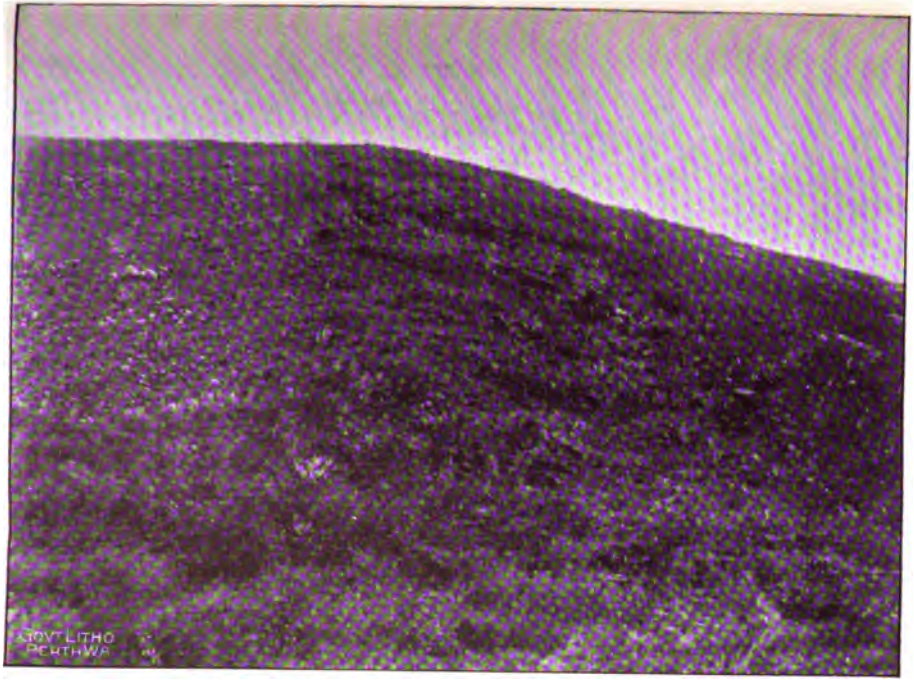

Photo. H. W. B. Talbot. **Neg. 417.**

A Greenstone Dyke traversing granite country.

points at which these superficial deposits have been penetrated either by shafts or trenches, their nature can only be surmised.

It is, apparently, a magmatic intrusion from which off-shoots have penetrated and shattered the granite in a south-easterly direction, the massive greenstones themselves have also proved to be intruded by dykes of quartz-diorite, camptonite, kersantyle, pegmatite and felsite, whilst the quartz reefs which were worked for gold in the shallow ground passed into basic dykes at a depth.

This area was originally densely covered with mallee scrub, in which belts of good timebr were occasionally met with, the whole being usually much matted with creepers, which adds to the difficulty of its examination, whilst all positions must be fixed by traverse.

In and around Ravensthorpe the principal copper lodes are contained in large off-shoots of this rock, or at its contact with the granite, whilst at Kundip a mass of considerable extent also encloses the lodes.

The Kundip Series.—This series of rocks, which are most largely developed near the township of the abovenamed, consist principally of sandstone (often ferruginous), grits, quartzites (ripple marked) and conglomerate. They are, undoubtedly, of marine shallow water origin, their deposition taking place at a period when the existing Ravensthorpe range formed the coast line, since high up its flank are boulder beds, composed of water worn masses derived from the banded ferruginous quartzite reefs; these beds further from the range pass first into pebble conglomerates and then into quartzites, the latter being often of so white a character as to be mistaken for quartz.

In the northern section of this area this series is only represented by a few small isolated patches of highly ferruginous sandstone, these being the only remaining evidence of the once considerable horizontal extent of these beds.

Near the Explosives Reserve one of these small outliers occupies so peculiar a position that at one time considerable doubt existed as to its origin since in its general character it presents a striking resemblance to a dyke; however upon a careful microscopic examination of the rock it proves to be a ferruginous sandstone, and therefore must have resulted from the infilling of an open fissure with sand from the surface.

The sand plains or superficial deposits probably also belong to this series, the sand of which they are composed being due to the weathering of soft sandstone.

The age of these beds is uncertain, since owing to their shallow water origin the wave action would have destroyed all traces of organic remains, but is is highly probable that they belong to the Great Australian Bight series (classed as Tertiary), which extend along the south coast from the westward of Albany far into South Australia.

The Lodes.—So very little work has as yet been performed upon the lodes of this district, and this little with the exception of one or two mines, is confined to the zone above the ground water level, that it is premature to make a definite statement as to what the permanent character of these bodies will be at a depth.

They may, however, be provisionally divided into two groups or classes of distinct type, the first of which are basic cupriferous dykes, and the second are apparently siliceous and ferruginous deposits filling leaching channels along the rock jointing, and therefore give less promise of permanency.

Without exception, all the mining upon this field has been confined to the fracture zone, and with only one or two exceptions to that portion of it which is situated above the permanent ground level which may be called the zone of aeration, whilst that below may be termed in contra-distinction the zone of saturation, and since no mining has been carried on in the zone of cementation which would here be represented by the lower section of the saturated zone and the waterless ground beneath it.

In this district the passage from the zone of aeration to that of saturation does not appear to have produced that marked physical change in the character of the lode and ore which is so usually met with and expected, since unaltered rocks containing the primary sulphides occur at a considerable elevation above the ground water level, and even in some cases quite near the surface; therefore it will be better to discard the above classification, substituting that which adapts itself more closely to these local conditions, viz., into the oxide and sulphide zone, the former of which covers that portion of the lode in which oxidation, hydration, and weathering have taken place, and the latter that in which the rocks in an unaltered form carry primary sulphides.

The question of primary sulphides occurring above the ground water level has been carefully investigated, and the only solution which can be arrived at is that the great density and impermeable character of the rock matrix have resisted weathering, and thus protected the enclosed ore from the oxidising influence of the descending aerated water.

The lodes at the surface present all the characteristics which are usually associated with deposits of copper ore, viz., ferruginous gossan outcrops (iron hat) of often considerable size and usually highly siliceous, the only indication of copper when present being minute traces of green carbonate.

These quartz and gossan outcrops usually carry fairly high gold and silver values, so much so in many instances as to cause them to be classed as auriferous lodes, whilst copper if present occurs in such small quantities as to be of quite a secondary consideration.

In prospecting these outcrops in order to ascertain their copper values it has been necessary, in many cases, to sink to as great depth as 40 feet before payable ore was encountered, when it most usually consisted of a ferruginous mixture of both oxides and car-

Photo. H. W. B. Talbot. Neg. 409.

White Quartzite Cliffs near Kundip

bonates (liver colour ore) with small green crystals of malachite contained in the cavities.

In this upper portion of the lode the ore occurs in bonanza-like enrichments either in a bunch-like form within the main body or more commonly in flat lenses upon one or the other of the walls. These have been called shoots by the miners, but since they are of purely secondary origin, and lack vertical continuity, this term has been decidedly incorrectly applied. The matrix or "formation," as it is usually called near the surface, consists of soft brownish clay which passes imperceptibly into weathered mica schist, then into schistose greenstone, and eventually into a solid basic dyke stone. Quartz is fairly plentiful in the zone of weathering, but below it mostly occurs in veins or layers which give the lode a banded appearance.

Both the gold and silver appear to be principally associated with the ironstone and quartz, a lesser quantity being carried in the copper ore whilst the percentage of these precious metals, particularly the gold, shows a marked decrease downwards in the lode.

The transition from the oxidised to the sulphide ores is usually sudden, there being no rich oxides and native copper capping a zone of secondary sulphide enrichment, but directly the solid rock is encountered, chalcopyrite occurs usually coated with green carbonate or more rarely coverite. ,

In the sulphide zone the chalcopyrite is associated with pyrites, marcasite and pyrrhotite (the latter largely predominating in the Cattlin mine), disseminated through the entire dyke mass or occasionally as lenses or pipes of ore upon one or the other wall of the formation.

In the unaltered sulphide zone there is an appreciable falling off in the gold and silver values, whilst a further steady reduction takes place even within this zone level by level downwards, thus clearly indicating that the higher values in the oxidised zone, and the upper portion of the sulphide zone are solely due to concentration, and to the deposition of gold from alkaline sulphide solutions.

Quartz too is largely a secondary mineral being deposited as metasomatic action has taken place in the lode channel, this being clearly demonstrated in nearly all the mines since lodes consisting almost entirely of quartz and ferruginous gossan at the surface pass into massive greenstone often almost destitute of quartz at a pth. The proportion of iron has also considerably increased ar the surface, owing to its deposition from ascending solutions awn to the surface by capillary action.

The fairly concentrated bunches of copper ore in the oxidised ne are evidence that secondary enrichment has taken place whilst e barren iron caps also indicate a leached zone, as however, no ondary sulphide enrichments occur, these bonanzas cannot as is ally the case have been derived from their oxidation. It is pro- le, therefore, that the carbonates and oxides of copper ha[illegible]

leached out of the lode cap by descending meteoric waters charged with organic acids, and subsequently redeposited as carbonates and oxides at a lower level when their solutions came in contact with the alkaline salts which the surrounding granitic rock contains in large quantities.

This alkalinity of the rocks, and in consequence that also of the ground waters has probably played an important part in the prevention of the deposition of secondary sulphide, since such water would immediately neutralize all acid solutions formed from the decomposition of the primary sulphides, and convert the copper directly into carbonates (as demonstrated by the carbonate coated chalcopyrite) therefore at the ground water level no acid solutions could be present from which copper could be deposited as a secondary sulphide upon coming in contact with chalcopyrite or marcasite.

As previously mentioned, traces of covellite are sometimes present coating the chalcopyrite, but since these are usually only met with along the lines of fracture it would appear that at these points a preponderance of acid must have been liberated owing to the more rapid decomposition of the ore, thus producing conditions favourable to the deposition of secondary sulphides.

At the deepest points of the richest mines the ore usually has a foliated structure, consisting of bands of quartz, greenstone, and chalcopyrite, or one of the iron sulphides, which layers do not occur with that ribbon-like regularity characteristic of many ore bodies in which the mineral matter has been deposited, layer by layer, from solution upon the sides of an open fissure, but of that lenticular form peculiar to schists, while the poorer portions consist more largely of greenstone schist containing only disseminated sulphides. Besides these two forms, as before mentioned, sheet-like lenses of variable size and richness (called shoots) are of common occurrence, forming upon either one of the walls; whilst extending from these into the adjoining wall rock (which is often granite) as well as into the formation itself are disseminations of ore, which apparently indicate that these rich bodies are due to metasomatic action, subsequent to the deposition of the cupriferous dyke.

Exactly under what conditions these were formed it is difficult to determine, since it is usually acknowledged that chalcopyrite is a primary sulphide, whilst these bodies decidedly present all the characteristics common to secondary or replaced deposits.

There are authentic instances in which chalcopyrite has replaced certain organic substances, and since marcasite is commonly of secondary origin there seems to be no reason why it should be necessary to wait until chemists decide the exact reactions that have taken place before a fact can be admitted. That chalcopyrite does occur, both as a secondary as well as a primary mineral, there can be little doubt, since large and rich bodies of this class of ore are usually met with immediately below the secondary sulphides, whereas comparatively lean ore only is often found to immediately follow it as greater

Photo. H. W. B. Talbot. Neg. 411.

Basal beds of the Kundip series, Western Steere River.

depths are reached, or in other words, that the upper portion of a lode, after the so-called primary sulphides are encountered, is invariably richer than the zone below it, although no copper ore other than chalcopyrite be present.

One point of particular interest with regard to secondary enrichment is noticeable upon this field in those lodes which cross the foliation of the rocks, the richer portions in which being apparently governed by the character of the country rock at the point of intersection, thus we find these zones of enrichment tilted upon the fissure plane at an angle coincident with the inclination of the rock folii, which give them a definite shoot-like appearance, whilst the intervening sections in the lode may be either barren or carry only gold values. In some instances the cupriferous sections have appeared to turn off from the main fissure on to the planes of foliation, or to put it the other way round, lodes which at their outcrops appear to follow the foliation of the rocks are found at a depth to swing round on to the main fissure plane, a good instance of which is exhibited in what is known as the "ironcap lode" in the Flag mine, in which the ferruginous gossan outcrop has a course of north-west and south-east, with a dip to the north-east; this at the 70ft. level has a course east and west, with a dip to the south and tilt to the east, *i.e.*, the intersection of the planes. Similar occurrences probably will be met with at one or two other points in the same mine, one of which is called the "eastern leg," but in this case the ore pipe has left the intersection of the planes and followed the foliation to the north-east, whilst the point of intersection of the two could not be examined since it is situated further to the eastward than the present end of the 100ft. level.

It is apparent that a main east and west fissure has intersected a series of normal north-westerly low-grade cupriferous dykes, from which it has been enriched at the point of intersection, and since a considerable portion of the high grade ore that has been obtained from this mine came from veins having a north-westerly course, it is probable that the main lode, the course of which is south of east, is not cupriferous in a primary sense, but has simply been fed at certain definite points called shoots.

As previously stated, a large number of these lodes may more correctly be described as auriferous than cupriferous, owing to the greater value in gold; in some instances, these, as before described, make into copper lodes at a depth with greatly diminished gold values, but there are also a series which lie in the greenstone area to the north-west corner of the map, which although undoubtedly of the same character as the others have proved when the gold practically gave out to carry too low copper values at their lowest levels to be payable.

These lodes are very highly siliceous near the surface, in fact they may be termed quartz reefs or ferruginous quartz reefs, according to the quantity of iron gossan contained. With depth, however,

they assume the usual schistose character, and are often heavily charged with marcasite, and also carry a little copper, whilst deeper still they assume a more basic character, with in places almost a disappearance of quartz. They were worked entirely for gold, some giving very considerable promise when first discovered, but the so-called shoots were short and values fell so rapidly that they are now practically abandoned.

The conclusions drawn are that those cupriferous dykes, which are of sufficient size to warrant deep mining, will prove when the fracture zone is passed to consist entirely of highly basic rock, through which iron and copper sulphides are disseminated, whilst quartz will have almost entirely disappeared and the gold and silver only in practically negligible quantities.

Of the other class of ore body there is little to be said, as they are simply leaching channels which follow the joins in a perfectly kaolinized schistose rock, so altered is this rock that 40 feet were sunk in it by the original prospectors to the vein, under the supposition that it was alluvium. They consist of a belt of kaolinised rock intersected by a series of veins of ferruginous quartz radiating from a main one, the whole of which is often auriferous. They have little inclination, starting from an anticlinal fold, at the apex of which it was small, but very rich stone was obtained at the lower levels. Values are rapidly falling, and will probably shortly become too low to be payable; it is possible, however, that others will be found occupying positions below the ones at present being worked.

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PART II.—Description of the Crystalline Rocks of the Phillips River District.

By E. S. Simpson and L. Glauert.

A most varied and interesting series of igneous rocks is represented in the collections of Messrs. Woodward, Montgomery, Blatchford, and Talbot. They range from a normally acid granite through intermediate types to a serpentine, and the study of them is complicated by the large development of hornblende and plagioclase not only in the amphibolites and intermediate rocks but also in the granites, and by the varying texture exhibited by one and the same rock.

GRANITIC ROCKS.

Soda-Granite.—The granite of this district is of an unusual type being almost devoid of orthoclase, the place of which is taken by a soda felspar. Its chemical composition is shown by analyses of [8139] and [8151].

	[8139] Well 25 chs. S. of No. 2 Tank, Ravensthorpe.	[8151] Western Well on W.R. 7517, Ravensthorpe.	Saganaga Lake, Minnesota.
SiO_2	70.27	68.11	69.34
TiO_2	.12	.74	*n. d.*
CO_2	.20	.21	*n. d.*
P_2O_5	.12	.28	*n. d.*
H_2O combined	1.08	.86	1.17
K_2O	.64	.76	.71
Na_2O	4.64	4.58	4.33
CaO	1.76	3.79	3.43
MgO	1.87	1.75	1.18
MnO	.20	.16	*n. d.*
FeO	1.22	2.99	*n. d.*
Fe_2O_3	.97	.11	2.46
Al_2O_3	16.11	15.77	17.25
FeS_2	.09	.17	*n. d.*
H_2O hygroscopic	.10	.11	*n. d.*
	99.39	100.39	99.87
Sp. gr.	2.70	2.74	*n. d.*

The most noticeable features of these analyses are the small percentage of potash and large percentage of soda, and the unusually high percentage of alumina. This latter is interesting as explaining the occurrence of andalusite in the granitic schists. The closest approach to this rock in chemical composition that we can find is the Granite (Amadorose) of Saganaga Lake, Minnesota, the analysis of which is quoted above.

In hand specimens the rock is light grey to dark grey or green in colour, and in texture and appearance varies from that of a typical coarse grained granite [**8151**] and [**8332**] to that of a medium or fine grained diorite [**8147**] and [**8318**]. In some specimens, notably [**1875**] and [**8147**], the hornblende crystals are large and very clearly defined.

Under the microscope quartz is found to be an important constituent in all cases and would appear to be the final product of crystallisation. Plagioclase and deep green hornblende are both very plentiful, the latter largely idiomorphic and evidently the first of the main constituents to crystallise out of the magma. Some ilmenite and biotite occur in nearly all examples, whilst zircon and apatite are seen in some of the sections.

Quartz-Ceratophyre.— Acidic dykes do not appear to be plentiful, but undoubtedly fine grained offshoots from the soda-granite are represented in [**8315, 8364, 8553, 7825**]. Surface specimens of this rock are pale grey in colour, but a specimen [**8553**] from a depth of 400 feet in the Mt. Cattlin Mine is very dark grey. It has a specific gravity of 2.68 and contains 71.01 per cent. silica, 0.55 per cent. potash, and 5.36 per cent. soda. These rocks are all very close-grained with occasional phenocrysts of felspar and quartz.

Albite Pegmatite. —Some very interesting specimens of a very coarse-grained pegmatite have been collected. The chief constituent of this rock is albite, both granular and very coarsely crystallised. In places it is of a pale bluish green colour. Some of this mineral with a coarsely lamellar structure was analysed, with the results given below.

Associated with the albite are coarsely crystalline spodumene (see analysis below), pink and green tourmaline, muscovite, lepidolite and quartz. See specimens [**1863, 8347, 8487, 8488**].

Analyses of Spodumene and Albite.

	Spodumene.	Albite.
SiO_2	61.94	69.13
Al_2O_3	26.48	19.44
FeO	1.82	*Nil*
MnO	trace	trace
CaO	.28	*Nil*
Li_2O	7.02	*Nil*
Na_2O	1.93	10.83
K_2O	.47	.04
H_2O combined	.29	.17
	100.23	99.61
Sp. gr.	3.14	2.63

Two miles south-west of Cocanarup is a pegmatite which is in places a typical graphic intergrowth of felspar and quartz [1855], in others exhibits much muscovite or lepidolite [1859, 1861].

Andalusite Schist.— Two specimens of rock [8463] and [7827] are composed mainly of a fine grained base of sericite in which are embedded numerous crystals of andalusite. These, and a foliated hornstone [8143] largely composed of andalusite, are evidently alteration products of the soda-granites.

Mica-Chlorite Schist.—In places, as the result of the crushing of the soda granite, accompanied by development of sericitic mica at the expense of felspar, and chlorite at the expense of hornblende, we find a mica-chlorite schist formed. See [8311, 8364, 8366, 8567.]

The following are detailed descriptions of some typical sections of these granitic rocks:—

[8151] Sec. 880. Soda-granite, Western Well on W.R. 7517. Coarse grain. Quartz and felspar about equally abundant. Quartz with numerous inclusions mostly "dusty" but some fine spicular, the former under high powers are seen to include minerals and liquids with gas bubbles. Large prisms of apatite are seen in some of the quartz masses. Felspar mostly multiply twinned and much clouded with granular grey matter. Brown biotite is the chief ferro-magnesian mineral, much green hornblende being associated with it. A little ilmenite is present in fine and coarse grains partly altered to leucoxene, also a little pyrites in patches. The ferro-magnesian minerals evidently preceded the felspars in crystallisation, quartz being the last constituent to settle out.

[8139] Sec. 877. Soda-granite, W.R. 4. This is a somewhat darker rock than [8151] and has a coarse texture. White felspar is altogether absent, to the greenish albite no doubt being due the deeper colour of the whole. Although the analysis given above has shown the rock to have a higher percentage of SiO_2 than [8151], the quartz only takes the second place in the micro-section examined, it has a very similar appearance to that in the section just described, except that the stringy arrangement of the enclosures is perhaps more marked. The felspar is cloudy and in this case contains needles and rods of apatite and fragments of hornblende, it shows some fine examples of the usual repeated twinning on the Albite plan. The strongly pleochroic hornblende needs no remarks except that it is very full of enclosures and has a very ragged outline. Ilmenite is present in fair abundance. Order of crystallisation evidently the same as in [8151].

[8147] Sec. 876. Soda-granite, near W.R. 7607. A coarse-grained rock similar to the preceding but much darker owing to the large development of hornblende. This is the most prominent constituent; there is a fair amount of felspar and some quartz. Under the microscope felspar and hornblende are seen to form the main mass of the rock, the former is idiomorphic as regards the quartz, cloudy owing to alteration and mainly composed of the plagioclase variety. The hornblende is very brilliant, generally

green or yellow according to the section's direction; at times it is brown owing to iron staining and in many cases gives splendid examples of twinning parallel to the orthopinacoid. The quartz is well represented and in some instances, besides the usual style of enclosures noted in the other sections, mica (biotite), ilmenite (leucoxene), and zircon are present, also fine needles of rutile or tourmaline similar to those noted in [8151].

[1875] Sec. 106. Soda-granite, three miles west of Mt. Desmond. This is slightly different in appearance to any previously described. It is coarse grained with much white felspar and some clear quartz, in which are imbedded numerous well defined long and somewhat narrow crystals of hornblende. Under the microscope the allotriomorphic character of the quartz is very evident. Crystals of apatite are not seen, but on the other hand many fine, long, slender needles of a dark brown mineral (tourmaline or rutile?) are found besides the usual small enclosures of minerals, liquids, and gases. Plagioclase is the chief felspar and often shows repeated twinning and large patches of decomposition products. Deep brilliant green hornblende is very abundant being represented by large well defined crystals, frequently twinned, and enclosing somewhat numerous grains of iron ore and rods of rutile, generally arranged along the cleavage lines. A little pale secondary hornblende is present as also a little biotite in places.

[8152] Sec. 881. Soda-granite, near W.R. 8358. A somewhat finer grained rock than any of the previous ones, in which pale grey felspar is the most prominent constituent. Small crystals of hornblende are very uniformly distributed. Under the microscope the chief constituent is seen to be felspar, much clouded and, for the most part, devoid of twinning. It contains numerous enclosures of apatite. The quartz which is about equally abundant contains dusty and fine spicular enclosures. Green and brown biotite is common, sometimes intergrown with muscovite. Dark green hornblende is abundant in coarse crystals, with a little ilmenite. Occasional crystals of zircon are seen.

[8318] Sec. 904. Soda-granite, W. R. 7385. A fine grained grey rock. Much clouded felspar, devoid of twinning, forms the greater part of the rock. Quartz and hornblende both abundant. The quartz contains numerous enclosures, apatite, rutile (tourmaline?), hornblende and zircon are recognisable. Also liquid and gas inclusions, the cavities sometimes taking the form of negative crystals. Some ilmenite partly altered to leucoxene.

[8310] Sec. 900. Altered Soda-granite, M.L. 236, Oversight Extended. A fine grained massive rock. Under the microscope cloudy patches of felspar are still visible, though boundaries are very ill defined and the usual interference effects barely distinguishable. Finely granular quartz, hornblende, biotite, ilmenite and epidote make up the balance of the rock which is inclined to be slightly gneissic in structure.

[8553] Sec. 935. Quartz Ceratophyre, 400ft. level, Mt. Cattlin C.M. Dark grey, very fine grained, massive rock, with visible phenocrysts of quartz and felspar. Specific gravity of 2.68. Contains silica, 71.01 per cent.; potash, 0.55 per cent.; soda, 5.36 per cent. Under the microscope the rock is seen to consist of a fine grained crystalline ground mass of felspar (albite), biotite and quartz, in which are embedded numerous phenocrysts of cloudy felspar, mostly if not wholly plagioclase. Brown biotite occurs somewhat freely in phenocrysts. A greenish chlorite, some epidote and a few crystals of zircon are seen. Though quartz phenocrysts are not uncommon on the faces of hand specimens, none were included in the section examined.

[8463] Sec. 914. Andalusite Rock. Sunset Mine. This is a greyish sericitic rock showing many fine large crystals of flesh-coloured or pink andalusite. By the aid of the microscope we see that it is essentially composed of a sericitic ground mass containing fine porphyritic crystals of andalusite and some smaller ones of phlogopite or some allied mica. Many small masses of secondary quartz as well as small crystals of rutile and ilmenite and other unimportant assessories are easily to be distinguished.

[8143] Secs. 873 A to F. Andalusite Rock and Schist (Hornstone). Near M.H.L. 126, Ravensthorpe. This specimen is of exceptional interest in that it consists of an andalusite rock, similar to the above, a portion of which has been so crushed and squeezed that not only a schistose but also an "augen" structure has been superinduced. Six sections heve been made of this rock, both in the crushed and the uncrushed portions. In the latter as in [8463] we see numerous large and small phenocrysts of andalusite full of various enclosures, amongst which were recognised tourmaline magnetite and long slender needles that may be tourmaline but which are too slender to be determined with certainty. Smaller crystals of felspar, tourmaline and biotite are also present in a ground mass composed essentially of sericitic or chloritic material.

The crushed and altered portion shows the same constituents, which have been so much affected that they have assumed a flow structure, the large crystals, even the hard andalusite, being crushed and squeezed out of shape in a most remarkable manner.

[8311] Sec. 901. Mica-chlorite Schist. Near shaft of M.L. 236, Oversight Extended.

This is a greyish green rock having a schistose structure and a somewhat silvery sheen due to the small flakes of chloritic and sericitic material present. The microscope shows that the rock is an altered acid rock. We have a fair amount of quartz showing "strain figures" in a matrix composed of sericitic, felsphatic and chloritic material, the latter being most plentiful in those places where small crystals of rutile and iron ore indicate the former presence of ferro-magnesian minerals.

[8567] Sec. 969. Mica-chlorite Schist. Mount Desmond Mine. The general appearance of this rock is similar to the above in every way. Microscopical examination shows that here again the main mass of the rock consists of chloritic and sericitic material in small scaly masses, in this are many irregular pieces of quartz which on further examination are seen to consist of numerous fragments, the general appearance of which suggests a secondary origin. In places the rock is quite green owing to the great abundance of chlorite, and here again we find an abundance of rutile crystals (prisms, etc.) as evidence of the former presence of a ferro-magnesian mineral. Several hexagonal crystals of zircon are to be seen, being the prism with its two pyramids. Iron ores are also present, particularly in those portions of the field where the rutile crystals are most abundant.

ROCKS OF INTERMEDIATE BASICITY.

Large areas of "greenstones" of intermediate basicity, partly massive and partly schistose, are shown on the map, and associated in part with them several more or less distinct types of dykes, including (*a.*) Quartz diorites of two types, (*b.*) Diorites characterised by a very large preponderance of primary hornblende, (*c.*) Diabases in which the chief ferro-magnesian mineral is fresh or altered augite, (*d.*) Lamprophyres (Kersantites) in which the chief basic mineral is biotite.

Amphibolite.—One mile nor-nor-west of Mt. Desmond, close to the limits of the map, is a rock [**8322**], which appears to the eye to be composed wholly of very large crystals, of a somewhat light green amphibole. It is distinct in appearance from any rock within the area mapped, except perhaps [**8468**], and resembles some of the amphibolites of Kalgoorlie and elsewhere on the goldfields. Like them, it appears to be an altered pyroxene rock. (*See* "Serpentines."

Massive Diorite Rocks and Camptonites.—From the main mass of greenstone in the Northern part of the field come two types of rock—1st, a dark green massive rock, somewhat coarse-grained and seen under the microscope to consist almost entirely of deep green, well-crystallised hornblende, with a little interstital quartz and clear felspar [**8465, 8469**]. 2nd, a light to dark green rock, which, under the microscope, is seen to be fine grained, with a fine granular base of felspar, iron ore and usually quartz in which are embedded numerous small, and some large crystals of green or colourless hornblende [**7826, 8145, 8388, 8464**]. The structure of these dykes differs considerably from that of typical diorites, and partly because of their structure, partly because of their affinities with the kersantites, they are provisionally classed as camptonites. Biotite occurs in both types in variable amount.

Diorite Dyke Rocks with much Hornblende.—A number of dykes are composed of a rock which is almost wholly hornblende, the colouring of which is very distinctive, viz., rich blue green.

strong green and pale yellow [**8140, 8141**]. The interstital matter is mainly felspar and the rocks are either coarse or fine grained.

Quartz Diorite Dykes.—These differ somewhat amongst themselves, both in texture and composition, some being barely distinguishable from the previous mentioned rocks except for the quartz, the hornblende being very plentiful and of the same type as in the last group. Other specimens exhibit much quartz, whilst the hornblende is subordinate to the plagioclase. The hornblende in some tends to gather round nuclei, forming bunches 5 or 6 m.m. in diameter, and distant about 10 m.m. apart, and in these rocks chalcedony is somewhat freely developed [**8149, 8317, 8327, 8359**].

Enstatite Diabase.—A single example occurs of a very fresh coarse grained rock [**8144**] composed of clear multiply twinned felspar and augite, with subordinate hornblende, enstatite, ilmenite and quartz. A fine grained weathered rock [**6052**], consists largely of serpentine, with a structure which would suggest a pyroxene as the original mineral from which it is derived.

Kersantite.—In the Elverdton mine and its immediate vicinity, there is a fine grained dark coloured dyke rock, composed of a granular mixture of clear felspar and biotite, with a little hornblende and quartz [**8462, 7822, 7912**]. The silica percentage in a typical example [**8462**] was found to be 59 and the specific gravity 2.81.

Biotite Schist.—Biotite appears to develop readily at the expense of hornblende in all these rocks of intermediate basicity, giving rise ultimately to biotite schists [**1895, 1907**]. Examples occur at Ravensthorpe, Mt. Desmond and Kundip, and show all the features characteristic of pressure metamorphism.

Garnetiferous Schist and Eclogite.—A number of examples of greenstone schist are characterised by the occurrence of a garnet which, where determined, has proved to be grossularite. One such rock [**8155**], the chief constituents of which were green hornblende and plagioclase with subordinate iron ore, garnet, and quartz, has the following composition:—

SiO_2	62.23
TiO_2	1.51
CO_2	.23
P_2O_5	.28
H_2O combined	.34
K_2O	.29
Na_2O	1.47
CaO	6.16
MgO	4.09
MnO	.56
FeO	10.46
Fe_2O_3	.08
Al_2O_3	11.90
FeS_2	.79
H_2O hygroscopic	.07
	100.45
Sp. Gr.	2.96

Biotite is very freely developed in some of these rocks at the expense of the hornblende [**1906, 8533**], the schistosity of the rock being usually in direct ratio to the proportion of biotite present. The hornblende varies from almost colourless to dark green. The proportion of garnet present is very variable, but in all cases it appears to be a late development, as it encloses numerous fragments of the other minerals.

Chlorite Schist.—This does not appear to be a common rock on the field, but examples of it are present in the collection [**8311, 8366**]. They are evidently altered hornblende rocks.

The following are detailed descriptions of such of these rocks as have been examined in detail:—

[**8322**] Sec. 948. Amphibolite, one mile N.N.E. of Mt. Desmond. This is a greyish green rock showing large lath-shaped crystals of hornblende of irregular outline, some of them being as much as 30 m.m. in length. The whole rock has an altered appearance and suggests the presence of a good deal of chloritic material. The microscopical examination shows that the alterations typical of pyroxene rocks are very far advanced. We get no felspar, but just a mass of aluminous hornblende, altering pyroxene and chloritic or serpentinous material. Needles of tremolite are very common in the amphibole masses. (See Serpentines [**8154, 8326**]).

[**8144**] Enstatite Diabase, W.R. 7517, and

[**8568**] Enstatite Diabase, Mt. Desmond Mine. Though these two dyke rocks were obtained some distance apart they resemble one another very closely though [**8144**] seems somewhat fresher. The hand specimens show a medium grained dark blue or dark green rock with many bright faces of augite crystals, the whole being mottled through the presence of whitish masses and lath-shaped crystals of plagioclase. Traces of pyrites are also to be seen. Under the microscope the chief constituent is seen to be pyroxene. We have it in two habits, in some places an "ophitic" structure is developed whilst in other the augite takes the form of small granules. The mineral shows good examples of twinning, and often exhibits the characteristic cleavages of the group. Further examination shows that there is a rhombic-pyroxene as well as the monoclinic augite, and this, on account of its straight extinction, its almost total lack of colour and very weak pleochroism as well as its highly developed cleavage has been classed as Enstatite.

In [**8144**] some fine masses or crystals of this mineral are to be seen, one piece in particular being interesting, as it shows the decomposition gradually encroaching upon the whole mass; near the centre the mineral is still very fresh, but as the edge is approached chloritic material is seen to fill the cracks or cleavage lines, coming more and more in evidence, till at the extremity all the pyroxene has disappeared and we have simply a mass of

greenish and brownish chlorite adopting a rudely spherulitic structure, portion of which might be taken for serpentine.

Though twins of enstatite are rare, one was seen in [8568], in which the twinning was along one of the cleavage planes.

In [6052], from the Last Chance Mine, the enstatite and augite are more difficult to separate on account of the small size of the crystals, for in this rock as well as [8568] the ophitic structure has disappeared, and the whole of the pyroxenes are granular.

In thin sections the augite has very little colour and gives practically no pleochroic colours, but with the crossed nicols bright colour effects are obtained as well as unmistakable evidence of twinning.

Taken on the whole the mineral is very fresh, those alterations that have taken place being confined to certain portions of the slide. At the same time good instances can be seen, especially in the more coarse-grained examples, of the mineral altering into chloritic material; it being in some cases completely converted into spherulitic aggregates of chlorite which send out tongues into the surrounding felspar by means of the cracks and cleavage lines. In other examples every step in the transition from pyroxene to hornblende and biotite can be traced, the alteration even extending beyond this into a green chloritic material similar to that just referred to. Another alteration product of the ferro-magnesian minerals and the felspar may be noted here, it is Epidote which is to be seen in [8568] and [6052] usually taking the form of irregular yellowish grains showing slight pleochroism and bright colours with the aid of crossed nicols.

The plagioclase felspar of the rocks is very conspicuous, forming fine idiomorphic lath-shaped crystals which give fine examples of twinning on the Albite plan. The mineral is very fresh and clear, only occasionally showing signs of saussuritisation. Upon measuring the extinction angles of the twins it is found that in almost every case the mineral was well within the labradorite margin, 30 degrees or over. Quartz is also present as an original constituent as is shown by its micro-pegmatitic intergrowth with felspar in several of the slides examined [8144]and [8568]. Interstitial masses and grains are also present, and show by their outline that they were formed late on in the course of crystallisation, some of the masses may even be secondary, but that does not seem likely in this group of the Phillips River rocks. Apatite is a common inclusion. Titaniferous iron ore is also to be seen as an original constituent; some of the crystals, being in close conjunction with altered or altering ferro-magnesian minerals, are without doubt of secondary origin. The undoubted secondary minerals, chlorite, biotite, hornblende, epidote and serpentinous matter, have already been mentioned in passing. The most important one is hornblende; from its associations with the augite there is no doubt that this is purely secondary, for all the steps can be seen between

the unaltered augite to the fresh green hornblende with its clear colours, its fine cleavages, and in many cases its almost perfect outline.

Biotite both green and brown in colour is often associated with the hornblende as an alteration product, it is very fresh and shows few signs of decomposition, except for the presence of chloritic matter at the fibrous extremities of some of the masses.

[8140] Altered Diabase, near M.H.L. 16. This is a dark blue or blue black dyke rock showing many bright cleavage surfaces of hornblende. With the microscope it is seen that the rock is practically a mass of ferro-magnesian minerals and their alteration products, we see hornblende in large masses showing many twinned individuals giving fine examples of prismatic and basal cleavages, good pleochroism and very bright polarisation colours:—

a = Straw yellow.
b = Yellowish green.
c = Blue green.

Its structure and form suggest that it is of secondary origin Some of the masses are altering and passing into green chloritic material. Enstatite is present. Plagioclase felspar is represented by a few odd lath-shaped crystals. A little epidote seen, a grain or two at the most.

This rock is evidently very poor in felspar, and is either derived from a similar diabase or the felspar has disappeared entirely, being replaced by aluminous hornblende and chlorite.

[8328] Altered Diabase, near M.H.L. 67. In this the stages of alteration are further advanced, although some felspar (?) is present. It is a grey rock with yellowish patches and appears to consist entirely of hornblende, augite, and decomposition products (bastite, etc.).

Under the microscope we see that the main mass of the rock consists of chloritic and serpentinous material, imbedded in which are the remnants of many of the original minerals, the enstatite is converted into bastite, and the augite is present in very much more corroded masses than in [8322]. Felspar is represented by ill-defined and much clouded masses and patches, generally limited in extent and too impure to allow a determination of the group to be made. Iron ores are present in the form of grains and crystals, the former often filling veins penetrating the mass. In some parts, too, the ferruginous material has stained the adjacent minerals and alteration products.

Secondary hornblende giving bright polarisation colours and showing characteristic cleavage is not rare, generally it is very pale-coloured and fibrous, the needles often resembling tremolite. The rock is a serpentinous rock with bastite, and is clearly an altered form of an enstatite diabase.

[8317] Sec. 903. Quartz diorite with chalcedony, W.R. 7385. This is typical of this well-defined type of dyke rock which in-

cludes also [8149, 8327, 8359]. Plagioclase felspar is the chief constituent, its habit is usually lath-shaped crystals of rectangular outline, and in this group of rocks it is evident that in the majority of instances it is idiomorphic. On the other hand fields are seen in all the sections examined that give good examples of micro-pegmatitic intergrowths with quartz. As regards its structure, the felspar is very much altered, being almost entirely converted into saussurite from the centre outwards to the edges of the crystals. Sufficient evidence was, however, on hand to determine the presence of repeated twinning on the albite plan in the original unaltered mineral, this was seen to the best advantage in [8149, 8317]. Owing to the state of alteration of all the crystals it is impossible to say whether the mineral contained enclosures in its original state, the masses as now seen give no evidence of this. In some sections part of the slides show the presence of hornblende fibres and chloritic matter in the forms of granules and fibres as an alteration product of the rock. The quartz of this group is present in the usual irregular masses so much associated with the granites, and, as already mentioned, in micropegmatitic intergrowth with plagioclase felspar. The mineral, when compared with samples from other rocks, is very free from inclusions. When these are present they generally take the form of long narrow needles which show up in high relief (rutile or tourmaline), or are present as prisms and hexagons of apatite. Zircon was also seen in a similar rock [8149]. Silica is also present in a cryptocrystalline condition, and is a very distinctive feature of this group. Every slide gives good examples of radiating tufts and spherular aggregates of chalcedony usually associated with the quartz and in [8149] seemingly a decomposition product of the felspar.

The identity of the original ferro-magnesian mineral is a matter of some doubt, owing to the amount of alteration that has gone on since the rock was formed. An examination of all the sections shows that whereas its relationship to the felspar is distinctly allotriomorphic it is difficult to say how it stands with reference to the quartz on account of alterations that have taken place.

Some of the sections suggest augite in the long lath-shaped crystals so often associated with trachytes, and this is most likely the original mineral of this group. Whatever the primary mineral was, it has now quite disappeared, and in its place we usually get a greenish yellow or greenish hornblende with the characteristic habit and cleavages of the mineral, greenish chlorite and chloritic material and biotite.

The outward appearance of this rock suggests much altered hornblende, and the microscopic section proves its truth. Here we see practically none of the original mineral, its place being entirely taken up by secondary hornblende, altering hornblende, chloritic material and chlorite. This latter product can here be studied to

great advantage, every step of the change can be viewed, and it is seen to be much more complete than was shown in any of the other sections, the coating of the felspar crystals, the penetration of the chlorite and the alteration of the adjacent felspar into epidote is most apparent. Ilmenite and leucoxene are abundantly associated with the hornblende, etc., in this section.

[8149] Sec. 879. This is a medium-grained greyish rock consisting of felspar, quartz, and hornblende, with numerous segregations of the latter mineral, 5 or 6 m.m. in diameter and rarely more than 10 m.m. apart. The chief constituent is seen to be plagioclase, showing a tendency to form lath-shaped crystals and giving some examples of repeated twinning. Quartz is very plentiful and appears to have been the last mineral to crystallise out, it is clear, contains few inclusions, chiefly minerals (? apatite, etc.). Hornblende is scattered throughout the section, it is rather altered and iron-stained, has a greenish yellow hue, and is darker near the edge. There is a good deal of titaniferous iron present in the rock. Zircon, apatite, epidote, and chalcedony present as secondary minerals. A little fresh, clear, and bright secondary hornblende is to be seen at the edge of some weathered masses of the same mineral.

[8327] Sec. 907. Quartz Diorite near Elverdton Dam. This is a mottled rock of medium grain composed of masses of dark green or blue hornblende and white or greenish plagioclase. Under the microscope the rock is seen to consist of plagioclase, hornblende, and quartz with ilmenite (leucoxene) and apatite. As alteration products or secondary minerals may be mentioned epidote, chalcedony, secondary hornblende and chlorite. Plagioclase is present as the chief constituent, and it is very cloudy, so that it does not give good polarisation reactions, still its outline is very distinct, and suggests this mineral rather than orthoclase. It often contains small inclusions of the ferro-magnesian minerals present in the rock. Hornblende is present in two ages, the one brownish in colour and much iron-stained is idiomorphic and is fairly plentiful. In places it is changing into a bright green and fresh-looking hornblende, the nature of which can easily be determined on examining crystals placed adjacent to quartz and felspar. Quartz is very nearly as plentiful as the original hornblende. It contains numerous inclusions consisting of apatite, etc. Associated with it are many masses of chalcedony. A fair amount of ilmenite, changing into leucoxene, also epidote, chlorite, apatite, and zircon are present.

[8359] Sec. 910. Quartz Diorite. 25 chains N.W. of N.W. corner of G.M.L. 101, Ard Patrick. This is a medium-grained granitic rock, the chief constituents being white plagioclase felspar, at times inclined to be greenish in hue, and dark green hornblende which is generally in lath-shaped crystals. A little quartz could also be recognised by the aid of a lens.

Under the microscope cloudy twinned and untwinned felspar is seen to be the predominating constituent; its usual tendency is to crystallise out in long rectangular crystals, but in some portions of the slide a fine micro-pegmatitic intergrowth with quartz is seen, in others there is not the slightest doubt that the felspar is idiomorphic as regards the hornblende. The mineral is very cloudy and contains many inclusions of hornblende and chlorite.

The hornblende is present in two ages, the original mineral is brownish in colour and only slightly pleochroic, whilst its effect upon light with crossed nichols is not very marked. The secondary mineral, however, is a bright green, and gives bright colours and shows intenser pleochroism.

The older mineral is much altered, and is associated with a number of fine ilmenite crystals, and may have been formed before the felspar. The quartz is present in fairly large crystals and interstitially. On the whole it is very clear and free from inclusions, though a fair number of apatite rods are to be seen. Its micro-pegmatitic intergrowth with felspar has already been noted. A little brown biotite is seen and some chalcedony may be present.

This will be a quartz diorite rather more basic than [**8149, 8317, 8327**]. Chalcedony appears to be present; a little was seen but it was so limited in extent that it could not be seen to advantage.

[**8316**] Sec. 923. Quartz diorite. Near S.W. corner of G.M.L. 132, Darley. This is a medium-grained rock of a granitic type, it differs from all the other specimens from the district in the presence of pink felspar, the other components are hornblende and plagioclase, the ferro-magnesian mineral being slightly porphyritic.

Under the microscope the porphyritic structure is accentuated and it is seen that plagioclase is present in lath-shaped crystals and in smaller masses, being in fact the chief constituent. The rock is fairly fresh, and in consequence we get good polarisation results when compared with the other quartz diorites. In places micro-pegmatitic intergrowth with quartz is to be seen. Twins very common, giving an angle of 15 degrees (oligoclase-andesine).

The quartz is fairly abundant in small sized grains, and in larger masses, where it is associated with the felspar, it resembles the quartz of the other classes of rocks examined, in the presence of needles of rutile (or tourmaline) and prisms of apatite as inclusions, besides more minute crystalline matter that could not be identified. The ferro-magnesian constituent presents interesting features. The original mineral has become greatly changed; in places it is still present as a green hornblende, but as a rule it has become disintegrated, has altered into epidote and secondary hornblende, which is very fresh, and shows the characteristic cleavages, or has given rise to greenish chloritic material which

has spread into the adjacent minerals. The relationship between the felspar and the hornblende was difficult to ascertain on account of the alteration subsequent to crystallisation, but it is safe to assume that here again the felspar is idiomorphic, whereas the quartz is interstitial where not intergrown with the felspar. Ilmenite and leucoxene are present as accessories, and show their usual features, including skeleton crystals. Apatite is present in some fine large prisms. Biotite is to be seen in the masses of alteration products resulting from the decomposition of the original ferro-magnesian mass. There seems no doubt that some of the iron ores are the result of the same process of alteration.

[8148] Sec. 878. Quartz diorite, near M.L. 248, Red Hill. This is a medium-grained rock with white crystals of felspar and dark green hornblende in one part, whilst in the other portion the texture is finer and there are no large crystals. On one side of the specimen a layer or band of biotite covers nearly the whole surface, showing that the rock has been subject to a considerable amount of metamorphic action. The micro. section examined shows both the fine and coarse-grained rock. In the latter portion we find that altering plagioclase and secondary felspar (albite) are the chief constituents; the former is so much altered that the polarisation effects are quite obscured, and no determination is possible. The albite on the other hand is quite clear and fresh, and gives good opportunities of measuring the extinction angle—16 degrees.

The hornblende is very fibrous in its structure, but gives fine polarisation colours and quite distinct pleochroism. There is a good deal of iron ore present in the form of ilmenite, which by its relationship with the hornblende suggests very forcibly that both these minerals are the resultants of metamorphic action upon the original ferro-magnesian mineral, which contained much more iron than the present fibrous hornblende. Apatite is present as an original, whilst chlorite and biotite (enclosing lenses of quartz) and quartz are present as secondary minerals, though some of the last-named may be original.

In the more fine-grained portions we have the same minerals, but here they are all uniform in size, and we have a greater amount of secondary quartz and albite. The brown bleaching biotite is also much more abundant, the whole fine-grained mass reminding one very much of the Kersantites, though the colour of the biotite is not identical. In this rock the form of the hornblende is the most noticeable feature, for this variety is only rarely met with among the other rocks examined. We generally get a weathered or altering hornblende giving somewhat anomolous colours and a fresh secondary form in which—

a = straw yellow.
b = dark green.
c = blue green.

These colours do not agree with those given by the fibrous form

present in [8148], which reads very pale straw, green and pale blue.

Among this group of quartz diorite rocks there are several specimens which are much finer in structure; these are [8141, 8313, etc.], which will now be described, the latter shows white or pale patches which look like somewhat altered or weathered felspar, as [8141]. This, which we take to be the better sample, will be gone into first.

It is a blue-black compact rock showing nothing but hornblende crystals to the naked eye. By the aid of the microscope it is seen to consist of green or greenish hornblende usually in the form of fibrous masses somewhat similar to [8148], but not differing so much from the usual run of hornblende met with in the diorites. Under the microscope the general type of the rock is very like the diorites just described, the felspar (plagioclase) is present in idiomorphic crystals all much altered and in irregular masses. Some of them show signs of twinning and give polarisation colours, but not of sufficient value to enable the group of the felspars to be diagnosed. Albite, however, is present. The hornblende is very similar to that described before, and from its freshness is probably secondary. Very little quartz is present, and that which is to be seen is interstitial and secondary. No accessory minerals are recognisable in this rock. Among the chief constituents the hornblende is by far the most important, and is remarkable for the presence of small needles which are forcing their way into the felspar on every hand.

[8313] has already been described as regards the hand specimen. The micro slide shows the rock to be more altered than the preceding. The hornblende is very fresh and gives some splendid examples of basal and prismatic cleavages and twins, whilst all the masses give good pleochroism and polarisation colours. The felspar, which is taken to have been a plagioclase, is much altered, some masses being completely altered into saussurite, not a single mass being fresh enough to allow the determination as to group to be undertaken with success. The quartz is clear and contains fine prisms of apatite, but few other inclusions. Suggestions of micro-pegmatitic intergrowth with felspar are to be seen here and there. Ilmenite is present as skeleton crystals, and is evidently in part, if not wholly, an alteration product derived from the original ferro-magnesian mineral. Sphene and biotite are also to be seen as well as a little epidote.

[8565] This fine-grained rock is somewhat darker in colour, but its essential points agree with the two previous rocks. With the microscope we see that it consists of much altered felspar (saussurite) and green hornblende and chloritic material. The hornblende is much changed, and only in rare intervals gives good or fairly good polarisation results. Most of the ferro-magnesian mineral has undergone a great deal of change, and has even gone

as far as to be partially converted into chlorite. Secondary albite and quartz are abundant, filling up all the cavities between the larger masses of minerals. Here we evidently have to deal with a diorite that is very highly altered, indeed, perhaps more so than any other of the series; a rock, too, which may be found to be a connecting link between this group and the so-called "Camptonites" which are to be described later on.

[8465, etc.] Camptonites. These rocks are all fine grained, and of a grey-blue or grey-green colour. As a rule they show no definite crystals, though traces of cleavage faces and crystal faces can easily be seen even with the naked eye. The constituents are chiefly hornblende, which is present in large crystals of a secondary nature [7826, etc.] or in smaller crystals and grains [7825, 8465] that at times can scarcely be termed porphyritic. The felspar is sometimes represented by weathered porphyritic original crystals, but generally is only seen as one of the component parts of an albite quartz matrix or mosaic. Accessory minerals in the form of iron ores, etc., are to be seen. As the structure of some of these differs from the true camptonite type it has been thought necessary to draw attention to the fact before proceeding further.

The rocks themselves too show a diversity of structure generally however of a purely secondary nature. Roughly speaking, they may be divided into two or three classes. We have the series [8465, etc.], which show the following micro structure:—

The hornblende is very abundant, consisting of green and yellowish masses and lath-shaped crystals scattered promiscuously throughout the mass and adopting a rudely aggregated structure. Its general appearance is very characteristic, these remarks refer not only to its shape or form but also to its pleochroism and polarisation effects. The felspar as already mentioned is practically confined to the ground mass where it and quartz form a very fine grained mosaic so characteristic of secondary albite. Some of the sections, particularly [7825], show the remains of large twinning porphyritic crystals of plagioclase, which are much altered and full of needles and prisms of green hornblende. Brown biotite and epidote are also to be seen as secondary minerals.

In most of these sections we find small grains of iron ores (ilmenite, etc.), scattered all over the field. These it seems are the result of the alteration of the original ferro-magnesian mineral altering into a less iron-bearing form.

[8319] is a very similar rock to all the above, but shows signs of incipient schistosity in the parallel arrangement of the smaller hornblende prisms.

[8325] is a rock very similar to this group of Camptonites. We have the albite mosaic and grains of iron ores and the usual hornblende, this latter however seems to be altering into long, clear, colourless prisms or needles that may be an amphibole, but which are difficult to determine with certainty; the whole rock is very cloudy and is evidently altered and weathered.

The second class of Camptonites differs from the first in the presence of many long, clear hornblende crystals which seem to be forming out of and on the smaller masses of the earlier generation.

[7826] shows the albite mosaic and the grains of iron ore in their characteristic forms as noted in the earlier Camptonites. The hornblende, however, is different, the earlier generation is present in small fragments of a brownish hue, but are almost pushed out of existence by the many masses of the later amphibole. This is seen in long ragged masses and well defined crystals giving good cleavage lines and very characteristic pleochroism and polarisation results. Many fine twins are to be seen. Quartz is present in conjunction with the albite, copper pyrites fairly abundant, apatite seen. Biotite may also be present but is not easy to determine in this specimen.

[8145] is very similar to the preceding, the biotite is easily recognised whilst the remains of porphyritic felspar crystals are very prominent. A little apatite is also noticeable in long, slender rods.

The next three rocks, though they resemble the preceding to a great extent, have some features in common with the Kersantites, for instance, brown hornblende and biotite are becoming more prominent, so much so in fact that it is a matter of doubt whether they might not just as well be classed as Kersantites, which practically only differ from Camptonites in a greater percentage of biotite and a smaller amount of hornblende.

In this district, at any rate, the main features of the two groups and their constituent minerals only vary in their relative abundance in the main masses of the rocks. The biotite is not produced by pressure for no signs of schistosity can be seen on any of the specimens.

[8560] contains the remains of phenocrysts of plagioclase now converted into albite, a much greater abundance of hornblende and a good deal of ilmenite, giving some fine skeleton crystals. As before stated, all the minerals are very clear and look exceedingly fresh.

[8561] similar to the above, but with rather finer grained hornblende, more brown hornblende and biotite and altering felspar forming albite and quartz and sericite (?).

[8469] is practically an amphibole rock with a little interstitial albite quartz and iron ore. Even in the hand specimen the mass is bristling with crystals of hornblende showing their bright and glistening cleavage faces.

The "Camptonites" appear to pass by insensible degrees into typical Kersantite dykes, members of the former group being known with less hornblende and considerable biotite and of the latter group with much hornblende in addition to much biotite.

[7912] Sec. 947, Kersantite. 300 feet Mt. Cattlin Mine. This rock bears a great resemblance to [8469] the only noticeable difference being a greater proportion of felspar apparent to the eye; the presence of more veins and the presence in them of quartz and felspar.

Under the microscope it is seen at once that we are dealing with a different type of rock, whereas bluish green, green, yellowish green hornblendes are still the chief constituents as in [8469], the percentage of biotite has risen considerably. This ferro-magnesian mineral bears the same relationship to the hornblende as in the other rock, similar phenomena being noticed. Again there is a greater amount of weathered felspar and interstitial albite, together with the occurrence of rather more quartz and mica. From these facts it would not be indefensible to class this rock as a type intermediate between Camptonites and Kersantites.

The specimen examined is not very fresh, the hornblende has lost some of its clearness, the felspar (excepting the secondary albite) is very cloudy and the mica shows lenticular enclosures which in some cases are possibly calcite and in others (giving lower polarisation colours) are undoubtedly quartz. This biotite also shows signs of altering into a green decomposition product.

[8557] is very similar to the above, the minerals are smaller. The quartz is more equally distributed throughout the rock and augite is represented by a few small grains.

[7823] shows all the essential features of the above. Chloritic decomposition products are associated with the biotite and octahedra of magnetite make their appearance. Two porphyritic crystals of quartz are to be seen in the section round which the other constituents (chiefly the biotite) have formed themselves in a manner which suggest "flow structure" or "augen structure."

[8466] shows a general structure similar to the preceding but differs in the greater abundance of small laths of green hornblende and numerous octahedra of magnetite.

[8467] from a neighbouring mine shows much more olive brown biotite and less hornblende and has no quartz phenocrysts.

[7822] is like the preceding but contains two altering plagioclase crystals which are porphyritic.

[8462] is similar to the above showing a few quartz phenocrysts as well as the plagioclase.

[8468]. In this we have a rock very like some of the Camptonites as well as the Kersantites. In a ground mass consisting of a mosaic of albite, green prisms, rods, or laths of hornblende, etc., we have large porphyritic crystals of corroded biotite being altered into long fibrous crystals of a clear and colourless hornblende which gives fine colours and in places shows the characteristic cleavage. To increase the resemblance a fair amount of ilmenite and pyrites is scattered throughout the rock.

This will be an intermediate type which bears a greater resemblance to Kersantites just as [8560, 8561, 8469] swing towards the Camptonites.

[8155] Sec. 883, Hornblende-Eclogite. Ravensthorpe Range, east of Ravensthorpe. An analysis of this rock is given on page 27.

Microscopical examination shows a fair number of small pale pink garnets full of inclusions of the matrix, in a schistose mass of fine grained quartz, albite, hornblende, the latter often showing a tendency to form radiating tufts. A few larger phenocrysts of primary quartz and very cloudy lath shaped felspars are present. Ilmenite is abundant, a few grains of epidote, bright yellow in colour, are also to be seen. This is an altered rock of intermediate composition.

[1911]. This is very similar to the above, but contains numerous garnets and is rather darker in colour. The micro-section shows many pale clear garnets and a few large crystals of quartz and felspar in a matrix of quartz, albite and hornblende, the latter as in [8155] being very abundant. This is most likely a portion of the same rock altered in a similar way.

[1883] is similar to the preceding but paler in colour. Microscopical examination shows fine clear pink garnets full of enclosures and pale fibrous hornblende in a matrix of quartz albite and hornblende with countless grains of ilmenite bearing a great resemblance to some of the so-called "Camptonites."

[8533] is micaceous and schistose and is best termed a Garnetiferous biotite schist, the garnets are very numerous and of large size.

[1906] is very similar but has much smaller and fewer garnets.

ULTRABASIC ROCKS.

Serpentine.—The most basic class of igneous rocks is represented by an intrusion now all converted into Serpentine. On the surface this weathers largely into magnesite.

[8154] Sec. 882, Serpentine, ½ mile W.N.W. of the Last Chance mine. This is a mottled dark blue and greenish rock consisting of patches of green material in a dark blue base. Traces of a crystalline structure can be seen particularly at one edge of the specimen. The whole rock has a serpentinous appearance. Under the microscope the rock shows much green serpentine, as well as the remains of felspar crystals. From the structure of the former and the distribution of the magnetite it seems probable that the original rock was an olivine gabbro.

[8326] Sec. 924. Serpentine, 2 miles S. of M.L. 266. A blue black rock with yellowish-green patches. Under the microscope the rock is seen to be an almost pure serpentine with mesh structure and minutely fibrous. A fair amount of magnetite dust is present as well as some quartz grains. Evidently an altered peridotite.

See also "Amphibolite" [8322].

PHILLIPS RIVER ROCKS.

Rd. No.	Collector.	F. No.	Section.	Name.	Locality.
				Acid Rocks.	
1875	T B	..	106	Soda Granite	Three miles W. of Mt. Desmond
1898	T B	..	964	Do.	Jim Dunn Wonder, Ravensthorpe
7911	..	..	..	Do.	Bore Core
8139	H W B T	1	877	Do.	Well, 25 chains S. of No. 2 Tank, Ravensthorpe
8142	H W B T	4	872	Do.	10 chains S.E. from S.E. peg of Recreation Reserve, Ravensthorpe
8147	H W B T	9	876	Do.	10 chains N. of N.E. peg of W.R. 7606, Ravensthorpe
8151	H W B T	13	880	Do.	Western Well on W.R. 7517, Ravensthorpe
8152	H W B T	14	881	Do.	Near S.E. peg of W.R. 8358, Ravensthorpe
8305	H W B T	18	..	Do.	Pipe line, 10 chains W. of N.W. peg of 9977, Ravensthorpe
8306	H W B T	19	..	Do.	S.W. corner of Location 262, Ravensthorpe
8308	H W B T	21	..	Do.	15 chains W. of N.W. peg of Location 2, Cardinup Creek
8309	H W B T	22	..	Do.	Fault on bank of Creek, one mile South of M.H.L. 13
8310	H W B T	23	900	Do.	S. boundary of M.L. 236, Oversight Extended
8314	H W B T	27	965	Do.	M.L. 94, Amazement
8318	H W B T	31	904	Do.	Water Shaft on W.R. 7385
8330	H W B T	43	..	Do.	Road near S. boundary of M.L. 115
8332	H W B T	45	925	Do	20 chains E. of S.E. corner of Recreation Reserve 7369
8563	HPW	..	954	Do.	Mt. Benson Mine
8566	HPW	..	963	Do.	Mt. Desmond Mine

1912	TB	..	..	Felsite or fine-grained S. Granite	Half-mile N.E. of Ravensthorpe
1913	TB	..	..	Do. do.	Do.
8315	H W B T	28	..	Do. do.	Felsite Dyke, 20 chains S.W. of M.L. 28, Red Hill
8470	HPW	..	921	Quartz Ceratophyre	Mt. Cattlin Mine
8563	K	..	935	Do.	Do.
				Altered Acid Rocks.	
8562	HPW	..	968	Altered Soda Granite	Mt. Benson Mine
5291	Dr. Ch.	..	..	Sericite Schist	Phillips River
8321	HWBT	34	..	Do.	N.W. corner of M.L. 200, Last Chance Proprietary
8558	HPW	..	..	Do.	Mt. Benson Mine
8564	HPW	..	..	Do.	Do.
7827	M	..	837	Sericite and Andalusite Schist..	Elverdton Mine
8143	HWBT	5	873	Andalusite Rock and Schist ..	2 chains N. of N.W. peg of M.H.L. 126, Ravensthorpe
8463	HPW	..	914	Do.	Sunset Mine
8311	H W B T	24	901	Mica-Chlorite Rock or Schist	Near shaft of M.L. 236, Oversight Extended
8364	H W B T	58	..	Do.	One and a half miles W.S.W. of Kundip Tank
8366	H W B T	60	..	Do.	Mosaic Mine
8567	HPW	..	969	Do.	Mt. Desmond Mine
				Intermediate Rocks.	
1876	TB	..	..	(Quartz) Diorite	Three miles W. of Mt. Desmond
1884	TB	..	979	Do.	Near Dr. Jim Mine
1901	TB	..	970	Do.	Lady Annabelle Lease, Ravensthorpe
7824	M	..	834	Do.	Flag Mine, Kundip
8141	HWBT	3	871	Do.	20 chains E. of S.E. peg of Recreation Reserve, Ravensthorpe
8148	HWBT	10	878	Do.	Two chains from W. peg of M.L. 248, Red Hill
8307	HWBT	20	899	Do.	Dyke, 14 chains N. of S.E. peg of 10336, Ravensthorpe
8313	HWBT	26	902	Do.	25 chains N. of junction of Nangutup and Annabelle Creeks
8316	HWBT	29	923	Do.	Near N.W. corner of G.M.L. 132, Darby

No.	Collector.	F. No.	Section.	Name.	Locality.
				Intermediate Rocks—continued.	
8320	HWBT	33	949	(Quartz) Diorite	N.E. corner of M.H.L. 39
8303	HWBT	57	911	Do.	Dyke, 50 chains W. of Kundip Tank
8554	K	..	950	Do.	Mt. Cattlin Mine, Mullock Dump
8559	HPW	..	972	Do.	Mt. Benson Mine
8562	HPW	..	968	Do.	Do.
8565	HPW	..	791	Do.	Lucy Mine
1888	TB	..	31	Camptonite	Three miles N.E. of Cocanarup
7825	M	..	835	Do.	P.L.P. Lease
7826	M	..	836	Do.	South Cattlin Mine
8145	HWBT	..	875	Do.	Shaft on M.L. 12, Ravensthorpe
8319	HWBT	32	905	Do.	30 chains N. of N.E. peg of M.H.L. 9
8325	HWBT	38	906	Do.	On Creek, 10 chains W. of N.W. peg of M.L. 249, Ravensthorpe
8465	HPW	..	916	Do.	Mt. Cattlin Mine
8469	HPW	..	920	Do.	Do.
8555	K	..	951	Do.	Mt. Cattlin Mine, Mullock Dump
8560	HPW	..	953	Do.	Mt. Benson Mine
8561	HPW	..	967	Do.	Do.
7822	M	..	832	Kersantite	Elverdton Mine
7823	M	..	833	Do.	Mt. Desmond Mine
7912	HWBT	..	947	Do.	Mt. Cattlin Mine
8462	HPW	..	913	Do.	Elverdton Mine
8466	HPW	..	917	Do.	Mt. Desmond Mine
8467	HPW	..	918	Do.	P.L.P. Mine
8468	HPW	..	919	Do.	Elverdton Mine
8557	K	..	952	Do.	Mt. Cattlin Mine, South Lode

				Altered Intermediate Rocks.	
8324	HWBT	37	..	Altered Comptonite or Kersantite	W. bank of Jerducuttup Creek
8464	HPW	..	915	Do.	James Henry Mine
8531	HPW	..	..	Amphibolite	M.L. 110, Grimsley
1874	TB	..	..	Biotite Schist	Mary Mine
1895	TB	..	..	Do.	Federal Lease
1907	TB	..	..	Do.	Dallinson's Claim, Ravensthorpe
1909	TB	..	..	Do.	Kingston Mine
1906	TB	..	..	Garnetiferous Schist	Dallinson's Claim, Ravensthorpe
8533	HPW	..	..	Do.	Mt. Benson Mine
1877	TB	..	..	Garnetif Hornblende Schist ..	Three miles N.E. of Cocanarup
1883	TB	..	72	Garnet Rock	Mt. Cattlin Mine
1911	TB	..	..	Do.	Overshot Hill
2065	the Warden	..	..	Do.	Fitzgerald River
5289	Dr. Ch.	..	..	Garnet Rock Schistose ..	Phillips River
8155	..	17	883	Hornblende Eclogite	35 chains W.N.W. of N.E. peg of M.L. 227, Last Chance
				Quartz Diorites with Chalcedony.	
8149	HWBT	11	879	Quartz Diorite with Chalcedony	Annabelle Creek, W. of M.L. 14
8317	HWBT	30	903	Do.	W.R. 7385
8327	HWBT	40	907	Do.	Near Elverdton Dam
8359	HWBT	53	910	Do.	25 chains N.W. of N.W. corner of G.M.L. 101, Ard Patrick
				Basic Rocks—Dialases, etc.	
6052	M	..	766	Diabase	Last Chance G.M., Mount Desmond
8140	HWBT	2 6	973	Altered Diabase	10 chains N. of N.W. peg of M.H.L. 16, Ravensthorpe
8144	HWBT		874	Diabase	30 chains N.W. of S.E. peg of W.R. 7517, Ravensthorpe
8328	HWBT	41	908	Diabase altered, containing serpentine with bastite	Five chains S. of S.W. peg of M.H.L. 67

PHILLIPS RIVER ROCKS—*continued.*

Rd. No.	Collector.	F. No.	Section.	Name.	Locality.
				Basic Rocks.—Diabases, etc.—continued.	
8568	HPW	..	966	Diabase	Mt. Desmond Mine
8150	HWBT	12	..	Interbanded Acid and Basic Rocks	Annabelle Creek, 3 chains W. of M.L. 14
				Amphibolites, etc.	
8322	HWBT	35	948	Amphibolite	One mile S. of junction of Cardinup and Jerdacuttup Creeks
8154	HWBT	16	882	Serpentine	50 chains W.N.W. of N.W. peg of Quarry Reserve
8326	HWBT	39	924	Do.	Two miles S. of M.L. 266, Grand Seam, 10027
8534	HPW	..	..	Do.	McLeod's "Spec"
7828	M	..	838	Much altered Rock allied to above	Mt. Chester Tunnel
8361	HWBT	55	..	Much altered Rock	Near S.W. peg of T.A. 2
				Pegmatites, etc.	
1855	TB	..	29	Pegmatite	Two miles S.W. of Cocanarup
1856	TB	..	..	Tourmaline Granite	Do.
1860	TB	..	..	Mica Pegmatite	Do.
1863	TB	..	..	Spodumene Pegmatite ..	Half-mile South of Ravensthorpe
1863	M	..	..	Do.	From excavation at Head's Smelter
1878	TB	..	..	Pegmatite	Three quarters of a mile S.S.W. of Ravensthorpe, P.R. M.D.
5281	Dr. Ch.	..	..	Pegmatite	Phillips River
7956	..	..	..	Spodumene in Pegmatite ..	Cattlin Creek, W.R. 17
8529	HWBT	..	..	Pegmatite	W. of M.L. 74, Ravensthorpe
1885	TB	..	..	Jasper Rock	Near Dr. Jim Mine
5290	Dr. Ch.	..	..	Do.	"Phillips River"

				Sedimentary, etc.	
8 46	HWBT	8	..	Ferruginous Sandstone and Conglomerate	35 chains N.E. of S.W. peg of W.R. 7607, Ravensthorpe
8323	HWBT	36	..	Ferruginous Sandstone ..	N. side of Cardinup Creek, 50 chains above junction
8329	HWBT	42	..	Altered Sedimentary Rock ..	M.H.L. 290, King of Iron Knobs
8331	HWBT	44	909	Ferruginous Sandstone ..	E. boundary of Experimental Reserve 9109
8352	HWBT	46	..	Altered Shale or Mudstone ..	10 chains W.N.W. of N.W. corner of C.L. 130, Alice
8353	HWBT	47	..	Ferruginous Sandstone ..	15 chains E.S.E. of S.E. corner of M.L. 235, Victory
8354	HWBT	48	..	Do.	20 chains E.S.E. of S.E. corner of M.L. 242, Lone Star
8355	HWBT	49	..	Partly Metamorphised Sandstone	Near N. corner of G.L. 132
8356	HWBT	50	..	Do. do. ..	At Dam, on T.A. 2, near Flag Mine
8357	HWBT	51	..	Conglomerate	Near above (No. 8356)
8358	HWBT	..	52	Altered Shale	Three chains S. of S. corner of M.L. 251, (216) Harbour View, South
8360	HWBT	54	..	Argillaceous Sandstone ..	25 chains W. of N.W. peg of G.L. 107, Ard Patrick
8362	HWBT	56	..	Sandstone	30 chains S. of Kundip Tank
1914	TB	..	..	Quartzite (? a Dyke)	Half-mile N.E. of Ravensthorpe
7811	..	..	..	Saliferous Rock..	West River
8312	HWBT	25	..	Travertine with Shells	Salt Pool at junction of Anabel and Nangutup Creeks
6049	M	..	..	Auriferous Ironstone	Mt. Desmond

MINERAL CENSUS.

N.B.—The common rock-forming minerals are omitted from this list, except when cabinet specimens of them are obtainable. Those minerals of which good specimens occur freely are printed in capitals.

Record No.	Dana's No.	Mineral.	Locality.
7098, etc.	13	GOLD	District generally.
4436	31	Tetradymite	G.M.L. 43, Floater, Ravensthorpe.
8404	34	Molybdenite	Near Ravensthorpe.
6229 etc.	54	Chalcosite	G.M.L. 109, Mount Desmond and elsewhere.
6228	67	Covellite	G.M.L. 109, Mount Desmond and elsewhere
..	74	Pyrrhotite	District generally.
7909, etc.	78	Bornite	District generally.
8383, etc.	83	CHALCOPYRITE	District generally.
..	85	PYRITES	District generally.
8091, etc.	96	Marcasite	District generally.
6227, etc.	149	TENNANTITE..	Mosaic Mine, Kundip.
7812	166	Halite	West River.
5296, etc.	193	Atacamite	Detected in considerable quantities in several assay samples.
6246, etc.	224	Cuprite	District generally.
6223	230	Tenorite..	M.L. 7, Mary
1890, etc.	237	Magnetite	M.L. 143, Kingston Lease, etc.
4444, etc.	269	PSILOMELANE	East of M.L. 112, Mount Desmond.
5436	272	MAGNESITE	Kundip.
8351	288	MALACHITE	District generally.
6728	289	Azurite	M.L 206, Hecla, and elsewhere.
8490, etc.	316	ALBITE..	Ravens horpe (Head's Smelter)
7956, etc.	327	SPODUMENE	Ravensthorpe (Head's Smelter).
8125	338	Asbestos (Actinolite)	Phillips River District.
7964, etc.	370A	Grossularite	Near R 2, Cardinup Creek, etc.
8143	398	Andalusite	Near N.W. peg of M.H.L. 12, and Sunset Mine, Ravensthorpe.
8487–9, etc.	426	TOURMALINE, black, green, and pink	Ravensthorpe (Head's Smelter).
1861	458	Muscovite	Two miles S.W. of Cocanarup.
4443	458	Fuchsite	Phillips River.

1858, etc.	480	LEPIDOLITE	Cosmarup and Head's Smelter, Ravensthorpe.
8320, etc.	481	Serpentine	Two miles S. of G.M.L. 266, Grand Slam, etc.
8153	492	Kaolin	Quarry, 1 mile S. of M.H.L. 16, and elsewhere.
7012	493	Halloysite	Ravensthorpe.
8350	561	Olivenite	G.M.L. 99, Alice Mary, Kundip.
8350	601	Erythrite	G.M.L. 99, Alice Mary, Kundip.
8471	814	Scheelite	10 miles S.W. of Kundip and Dallinson's Reward, Ravensthorpe.

PART III.—Description of the Mines.

Historical.—The history of this field may be said to commence in 1892, when the Brothers Stennett discovered gold in small quantities in conjunction with copper and iron pyrites, but owing to the scarcity of fresh water in this locality and to the fact that sensational discoveries were made about this time at Coolgardie, the further prospecting of this district was for the time being abandoned.

The present writer crossed this field upon his way to act as the first Warden of the Dundas about this period, and was so favourably impressed with its mineral character that he strongly recommended further prospecting.

In the early part of 1899, the Dunn Brothers discovered auriferous quartz upon the western edge of the mining belt, not far from their homestead at Cocanarup, where they applied for a lease which they called the Jim Dunn's Wonder, but although the official statistics do not show any return from this lease, it undoubtedly drew attention to this district, for shortly afterwards a large number of others were pegged out and applied for to the northward upon the same line of country.

The original discoveries, as a rule, consist of fragments of auriferous quartz, scattered over a clayey surface, which was mostly covered with dense scrub, whilst the reefs had to be prospected for by trenching.

Prospecting in these early days was conducted under great difficulties on account of the scarcity of fresh water, whilst owing to the fact that the whole area is pretty thickly covered with poison plant, neither horses nor stock could be depastured.

The discovery of this belt of gold reefs was quickly followed by that of the copper lodes in the vicinity of Ravensthorpe, also at the foot of the range to the north-eastward, which are now known as the Mt. Benson group.

In the early part of 1900 Mr. Torrington Blatchford, Assistant Government Geologist, inspected this field, his report upon which, accompanied by a geological sketch map, was published in June of that year as Bulletin No. 5 of this Department.

On account of further discoveries being made during the same year, of the Mt. Desmond and Kundip Centres, a further inspection became necessary; therefore, the services of the present writer were requisitioned, his report appearing in the Annual Progress Report of this Department for 1901.

Early in the year 1903, Mr. A. Montgomery, State Mining Engineer, visited this field with the object of advising the Government regarding the erection of State Smelting Works, and his full report

in pamphlet form was published by the Mines Department in the same year. These smelting works were then erected and run with varying success, first at a position upon the Cordingup Creek, and later at the present site, which is about one mile to the eastward of the town.

The State Mining Engineer's report was supplemented by one dated June, 1905, published in the Annual Report of the Mines Department for 1904, and also by notes on the progress of the State Smelting Works in the Annual Reports for the years 1905 and 1906.

In the year 1906, these works were sold by the Government to the Phillips River Gold and Copper Company, Limited, who have now greatly increased their capacity by the addition of reverberating furnaces and a converter.

Towards the end of 1907, the State Mining Engineer was again despatched to the field with the object of advising the Minister as to whether the prospects of the district warranted the Government in the construction of a railway line from the Coast; his full report appeared in the Annual Report of the Mines Department for 1907. Mr. Cullingworth, the Inspector of Mines, also wrote several reports which appeared in the Press of the same year. Since many of the mines examined and reported upon by these officers are either closed down or an inspection of the upper levels is now impossible, it will assist very greatly in the study of these ore deposits if the reports above referred to are read in conjunction with the present.

The railway line is now an accomplished fact, whilst several good reservoirs have been constructed, which supply water both for domestic and mining purposes.

The Mines.—This field is at the present time passing through a period of extreme depression, which is very generally ascribed to what is called the "slump in the copper market," if, however, the market price obtained for this metal a few years back is recalled, it will at once be apparent that this cannot be the sole reason, since the present price is as high as it was at the inception of the field, the low value being more apparent than real, since it is only comparatively so with the abnormally high figure reached a year or so back.

The low market is, therefore, clearly not responsible for the existing state of things, which may with much greater reason be ascribed to the liberal Government assistance which has enabled men without capital to mine the richest portions of a number of lodes from the surface down to the water level and to dispose of the ore for cash at the State Smelters upon the most favourable terms, the result being that so long as the rich and cheaply worked bunches lasted, a mild boom set in, whilst this was further prolonged by the rise in the copper market above referred to, which rendered much lower grade ore payable.

Upon the top of this boom, certain capitalists secured options over a number of properties and upon these vigorous development

was commenced, with the result that a considerable impetus was given to business in the town, where a large number of new buildings were erected. Owing, however, to the sudden fall in the market, it was found impossible at the time to launch these mines successfully upon the London market, and, in consequence, some have been abandoned, whilst upon the remainder only a limited number of men are employed.

At the present time, a large number of the smaller mines are at a standstill, owing to the fact that the greater portion of the marketable ore above the water level has been raised, whilst funds are not available for the purchase of the necessary machinery to develop them further, the consequence being that the owners have been living in hope that the completion of the railway line would either cause a very considerable reduction in the smelting charges or a revival of interest to take place, which latter would enable them to sell out at a profit, but since these properties have, in the majority of cases, been so favourably reported on officially, a much higher price is expected than there is any likelihood of being obtained.

The condition of the small holders upon this field is, therefore, in a very bad way, which neither the railway line nor cheaper smelting can but temporarily relieve, for if during the boom time the lease owners were unable to purchase plant to work their mines below the water level, they have little prospect of doing so upon the realisation from lower grade ores.

There can be no question but that the future of this field is entirely dependent upon the introduction of outside capital, it is, therefore, to be sincerely hoped that those properties still held by the Phillips River Gold and Copper Company will develop up to expectations, for if such is the case, confidence will be established and many others will be taken up and worked. Should, however, anything unforeseen occur to cause this company to cease operations, this field may be considered as dead, for it would be impossible to induce persons to provide further capital for a considerable time upon the top of an acknowledged failure.

In the description of the mines which follows, the three main centres of Ravensthorpe, Mt. Desmond and Kundip, have been taken separately, whilst the first mentioned of these has been subdivided into three groups, called respectively, the Western, the Central, and the Eastern.

The first of these latter embrace the earliest discovered lodes, which are contained in what may be called the auriferous belt, but since these are now practically abandoned, any reliable information regarding them can only be obtained by reference to the official publications previously mentioned, and this remark also applies to certain of the copper mines in the Central and Eastern Groups of the Ravensthorpe Centre.

Generally speaking, the lodes are of one character, viz., basic intrusions, usually highly ferruginous and siliceous at the surface,

where they are, as a rule, practically destitute of copper, but fairly rich in gold, whilst in the balance of the oxidised zone they may, in addition to gold, carry a considerable percentage of copper, which occurs in the form of ferruginous oxi-carbonates. In the sulphide zone and below the water level, the gold values perceptibly decrease, or practically cease, whilst the copper and iron ores pass directly from carbonates and oxides into primary sulphides, with scarcely any indication of secondary sulphide enrichment.

The richer portions of both the copper and gold lodes above the ground water level, are purely secondary enrichment, lacking both size and definition, and, therefore, cannot correctly be described as shoots, whilst below it, the sulphides are mostly disseminated through a body of lode stuff of considerable size, upon which in only one or two instances, has sufficient development been done to prove their character.

With the exception of the Mt. Cattlin and the Elverdton mines, little has been done below the water level, therefore, it is at the present time impossible to state with any degree of certainty how these ore bodies will behave at a greater depth, but so far as the evidence goes they will, in the majority of cases, prove to be of too limited extent to be payable when the hard country is struck; others again promise to be a fair size, but of very low grade, whilst the remainder which are of considerable size, promise to yield a large quantity of low grade ore suitable for concentration.

Some of the mines are worked exclusively for gold, but these, like those in the Western Group, will, in all probability, make into low grade copper lodes at a depth when, even if the gold values do not fall, the veins are too small and the values too low to be worked profitably in the hard country below the water level.

In the copper mines proper, the ore has, up to the present, been hand picked, the higher grade sent to the smelting works and the more siliceous lower grade, if carrying high gold values, to the battery, by which latter process about 40 per cent. of the contents is recovered, whilst the sands, after passing over Wifley Tables, contain too high a percentage of copper to be amenable to cyanide treatment.

The returns furnished by the various mine owners do not represent the tonnage raised, since a large quantity of the low grade ore is thrown upon one side, whilst the balance is divided into two classes, one called firsts, or copper ore, and the other seconds, or crushing stone. The first of these is sold upon assay and the returns furnished being total metallic contents, whilst the second is crushed at a battery, when the extraction return is given, which, as before stated, is usually only about half of the total gold contents. The concentrates from the battery treatment are also smelted for copper, but the returns under this head do not show the total amount of ore from which they were obtained, but in its place only the tonnage of a concentrated portion, whilst the value given in pounds sterling

does not represent the sum paid for the ore, but the full market price at the time of the metallic copper contents of the ore.

Under the gold returns, upon the other hand, the number of tons crushed are given, but against this only the quantity of gold recovered by amalgamation, which is usually under half the contents. It will be apparent from this that the value of one portion of the ore is over stated, since no deductions are made for loss, but in the second it is not credited with the concentrates which actually are a portion of it, whilst the value of the ore is absolutely fictitious, because it represents the total metallic contents reduced to its highest state of purity upon the London market.

In the following table, the totals show all the ore treated, either by smelting or battery, the gold being the total of the assay returns from account sales notes added to the quantity recovered by amalgamation, and is stated in fraction of ounces per ton, whilst the copper contents is based upon a percentage of the total tonnage treated.

In the grand total for the last eight years of this field's existence, it is shown that the ore which, upon the average, contained 4 per cent. of copper and ½ ounce of gold, may be roughly valued at £4 10s. per ton. The very apparent falling off in the value of the copper ore production for 1908 is more apparent than real, being entirely due to the fact that the smelting works were closed down, therefore little ore was sold, whilst a larger quantity was crushed as seconds.

The usual practice of dealing with such questions as water supply, timber, fuel, fluxes, means of transport, smelting works, machinery and mining methods, together with the class, quantity, and suitability of the ore for smelting, concentration, or other metallurgical treatment, will not be touched upon here, since they have already been so exhaustively reported upon by the State Mining Engineer, to whose province they properly belong.

Table showing the Yield of Gold and Copper from the Phillips River Goldfield.

Year.	Ore treated.	Gold therefrom.	Rate per ton.	Copper therefrom.	Copper value.
	tons.	ozs.	ozs.	tons.	%
1900	34.00	36.72	1.08	10.18	30.00
1901	1,281.14	665.83	0.52	258.54	20.00
902	9,698.50	7,441.30	0.76	23.36	0.24
1903	9,741.08	7,050.73	0.72	214.59	2.20
1904	9.738.49	4,016.63	0.41	485.02	5.00
1905	5,098.54	2,563.26	0.50	307.66	6.00
1906	5,086.68	2,779.89	0.54	287.24	5.63
1907	14,104.62	4,313.87	0.31	658.73	4.67
To June, 1908 ..	3,611.38	1,718.18	0.50	62.95	1.74
Total ..	58,394.43	30,586.41	0.52	2,308·27	4.00

THE RAVENSTHORPE CENTRE.

This centre includes three quite distinct groups of mines which lie round the township from the north-eastward to the south-westward.

The first of these, which may be called the Western group, stretches in one almost unbroken line eight miles in length, which strikes in a north-east and south-west direction, the nearest point of which belt is about two miles north-west of the town.

These mines, without exception, were originally worked exclusively for gold, some of them carrying fairly high values near the surface; at greater depths, however, when the sulphide zone was reached, they invariably become poor.

There are only two in this group worthy of the name of mine, viz.: the Maori Queen and the Floater, the latter being the only one still held, although at present under exemption.

The second or Central group consists entirely of copper mines, which lie scattered in an irregular manner in the zone of dislocation which is situated immediately to the northward of the town, and extends as far as the Mt. Cattlin mine.

This group contains the original copper discoveries of this field and also the deepest mine.

The Eastern group are also copper mines, which lie in the contact zone close to the base of the range, but strike off from it in a westerly direction.

As before stated, the gold mines are practically all closed down, whilst with the exception of one or two of the copper mines they are pretty well in the same condition, the reason in the first-mentioned case being that the values gave out in the hard country, and in the latter practically all the accessible ore has been raised, whilst that in the hard country below the water level cannot be worked without machinery, even if the lode prove to be large and rich, of which in most cases there is very considerable doubt.

The Western Group.—In the greenstone area, which lies to the north-westward of the town, a belt of mines about eight miles in length have been worked for gold.

This group of mines, although the first discovered upon the field, have not as a rule been extensively worked, and are now mostly abandoned owing to the small size of the lodes, the limited extent of the payable stone, and the hardness of the enclosing rock below the water level.

Outcrops are of rare occurrence, the surface being usually covered by a layer of red clay about six feet in thickness, clothed by fairly dense scrub, the only indication of reefs being strewn fragments of quartz.

The lodes in this area are mostly siliceous and much iron-stained enclosed in a solid amphibolite country often intersected by small pegmatite dykes.

At a comparatively shallow depth, and before the ground water level is reached, sulphides of iron and copper make their appearance, and the lode matter passes into a schistose greenstone, whilst gold values materially decrease.

For particulars with regard to them reference should be made to the previous official reports mentioned in the introduction.

Table showing the Yield of the Mines of the Western Group—Ravensthorpe Centre.

Year.	Name and Number of Lease.	Ore treated.	Gold therefrom.	Copper therefrom.
		tons.	ozs.	tons.
1902	Alpha, G.L. 20	10.00	2.63	
1902	All for the Best, G.L. 3 ..	35.00	18.92	
1903–7	Bobby Dazzler, G.L. 115	18.00	38.59	
1902	Bridgetown, G.L. 15 ..	15.00	8.76	
1902	Christiana, G.L. 36 ..	50.00	13.14	
1902	Commonwealth, G.L. 10 ..	60.00	28.91	
1902	Coronation, M.L. 48 ..	31.00	18.14	
1902	Cousins Glory, M.L. 13 ..	80.00	32.46	
1902	Cumberland, G.L. 38 ..	20.00	3.50	
1902–4	Ellendale, M.L. 26 ..	70.00	36.80	
1906	Ellen Tommy, G.L. 93 ..	34.00	14.26	
1904	Eureka, G.L. 64	29.00	33.38	
1901–8	Floater, M.L. 21	12,881.19	10,933.81	.49
1902	Floater Proprietary, G.L.45	30.00	14.89	
1902–3	Golden Link (Day Light), G.L. 63	45.00	30.25	
1902–7	Grafter, M.L. 202	295.65	370.89	1.99
1902	Harwick, G.L. 41	15.00	8.76	
1901–4	James Henry, G.L. 26 ..	406.00	514.67	
1902–5	Jubilee (Diamond Jubilee), G.L. 75	124.00	58.94	
1902–3	Lady Jessie, M.L. 74 ..	77.00	58.43	
1902–4	Lucy, G.L. 21	269.00	174.78	
1902–3	Maori Chief, M.L. 4 ..	22.00	15.54	
1901–7	Maori Queen, G.L. 1 ..	5,086.17	4,100.53	.18
1902–7	Mt. Elya (Princess Royal), G.L. 88	160.50	106.07	
1903–5	Plantagenet, G.L. 76 ..	556.00	185.92	
1902	Sirdar (Two Bobs), G.L. 60	66.00	49.45	
1902	Waratah, G.L. 34 ..	6.00	2.06	
	Total	20,491.51	16,874.48	2.66

Maori Queen, G.M.L. 1. (Plate I.).—This the first gold-mining lease issued in this district, is situated about 2½ miles to the north-eastward of the township. It was worked for some years by the Phillips River Gold Mining Co., N.L., who equipped it with a battery and winding engine, and raised and treated over 5,000 tons of stone.

The lode, which has a north-easterly course, has been traced at the surface for a length of 8½ chains by a series of shafts and

From the Government Geologist's
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1910.

WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 36.

III.

Palæontological Contributions

TO

The Geology of Western Australia.

UNIVERSITY OF CALIFORNIA

BY

Dr. GEORGE J. HINDE, F.R.S.,

E. A. NEWELL ARBER, M.A., F.L.S., F.G.S., University Demonstrator in Palæobotany, Cambridge,

R. ETHERIDGE, Esq., The Curator of The Australian Museum, Sydney, N.S.W.

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Issued under the Authority of the Hon. H. Gregory, M.L.A., Minister for Mines.

WITH 12 PLATES AND 5 FIGURES.

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PREFATORY NOTE.

The eight contributions to which the Geological Survey is indebted to the authors have been received since the publication of the last palæontological Bulletin, No. 27, in the year 1907.

The first contribution, from the pen of Dr. Geo. J. Hinde, F.R.S., throws considerable light on the conditions prevailing in the Norseman District.

The second, by Mr. Newell Arber, M.A., F.G.S., is an important addition to our knowledge of the Jurassic Flora of Western Australia ; whilst that of Mr. Etheridge, the Curator of the Australian Museum, to whom the Survey is under a debt of gratitude, which it is difficult to repay, adds considerably to our knowledge of the organic remains of the Oolitic Beds of the Greenough River.

The description of *Sthenurus Occidentalis*, from the Mammoth Cave on the Margaret River, was prepared by Mr. L. Glauert, F.G.S., Field Geologist, for the information of the Caves Board.

The list of Western Australian Fossils, stratigraphically and zoologically arranged, which Mr. Glauert has drawn up to facilitate the work of the Geological Survey, will meet a much felt want at the hands of all workers in, and students of, Australian Geology.

The account of the New Fossils from the Barker Gorge, Napier Range, in the Kimberley Division, seems to point conclusively to the occurrence of undoubted Devonian Beds in this portion of the State.

The Notes on the Geological Age and Organic Remains of the Gingin Chalk contain evidence which points strongly to its being Cretaceous and not Tertiary, to which horizon it had previously been assigned.

A. GIBB MAITLAND,
GOVERNMENT GEOLOGIST.

Geological Survey Office,
Perth, 21st March, 1910.

1.—*On the Fossil Sponge Spicules in a Rock from the Deep Lead (?) at Princess Royal Township, Norseman District, Western Australia.*

BY

Dr. GEORGE J. HINDE, F.R.S.

Some months since Mr. A. Gibb Maitland, F.G.S., Government Geologist of Western Australia, forwarded to me for examination a sample of an earthy siliceous rock [8131] from the Deep Lead (?), known as the "Princess Royal," situated on the townsite of the same name at the eastern margin of Lake Cowan. Brief references to this deep lead (?) are given in Bulletin No. 21 (1906), of the Geological Survey of Western Australia, where it is stated that it was discovered in February, 1901, in carrying out alluvial workings for gold, mostly in the main street. The depth was 88ft. in kaolin.

Above the "wash" there is a white pug showing the usual slickensides and crush faces and above this ironstone gravel patches. The wash itself is mullocky, with concretions of a magnesian nature, and with quartz particles, etc. This wash is said to have been 30 to 40 feet wide, and about 6ft. in thickness on the west side, and below it there is a gritty brown material, evidently decomposed hornblendic rock.

At the Princess Royal townsite there is a strip of kaolinized ground about a mile long and a quarter of a mile wide, which may be either a remnant of a wider covering or be due to the felsite dykes in this locality being very susceptible to decomposition. At the south end of this patch the deep lead was found. No particular age can be assigned to this kaolin; it is probably mostly decomposed rock *in situ* and has been increasing in depth as long as this has been dry land (pp. 20, 36).

The reports from the Bulletin quoted above respecting the character of the deposits in this deep lead (?) do not make mention of any rock at all comparable with the sample which has been sent to me, and it may be hoped that further investigation will furnish some detailed information as to the thickness of the deposit from which the sample was taken, its position in the series exposed in the lead, and the character of the beds above and below it.

General Characteristics of the Rock.

The sample of rock examined consists of three small irregular lumps of a very light, whitish, finely granular, and powdery material, which is so incoherent, tender, and friable that it readily breaks up into dusty powder between the fingers, and when treated in water with a soft brush it passes into a greyish mud. It may be said to be an aggregation of fine particles without any cementing material to bind them together. There is no indication of bedding to be seen in the lumps. Treated with dilute hydrochloric acid, the rock shows no reaction whatever.

When the powdered rock is examined dry with a strong lens or by reflected light under a microscope, it is seen to be composed mainly of minute glassy rods and granules, and occasionally of entire sponge spicules. It addition to these remains of organic origin there are some minute grains of a dark mineral, and also more numerous clear granules, mostly of quartz. The larger part of the latter are angular or sub-angular, some are rounded, and others seem to be small crystals. †

The spicules of siliceous sponges are the only fossils recognised so far, in the rock sample, no remains of other siliceous organisms, usually associated in marine deposits of this character, such as radiolaria and diatoms, have been met with.

Condition of preservation of the Sponge Spicules.

The chemical constitution of the spicules of which this rock is mainly composed is closely similar to that of recent siliceous sponges. The silica is in the colloid condition and presents the same clear glassy aspect so characteristic of recent spicules and, as in these latter, it is negative in polarized light between crossed Nicols.

Exceptionally some of the spicules are of a milky tint with a porcellaneous appearance, similar to spicules in the Lower and Upper Greensand of the South of England (1) and in the Cretaceous Sponge-beds of Westphalia, and in a few cases also the spicular walls are traversed in all directions by very minute curved lines as in fossil spicules from Wiltshire (2). But the change from the normal glassy condition does not seem to have reached any further stage, and in no instance have I seen a spicule of chalcedonic silica in the material.

† "In my report on the Norseman material I mentioned that some of the quartz grains probably were partially formed in the rock, but I have since had an opportunity of showing these grains to Dr. J. S. Flett of the Geological Survey of Great Britain, and he considers that they have not been enlarged by a secondary deposition of silica, and that they have rather the appearance of having been derived from vein quartz. He further thinks that some of the fine portions of the rock in which the sponge spicules are embedded may be kaolin." G. J. H., 10th September, 1909.

(1.) Hinde. Sponge Remains in the Lower and Upper Greensand of the South of England. Phil. Trans. Roy. Soc., Vol. CLXXV. (1885), p. 426.

(2.) Ibid pl. XL., fig. 8.

The axial canals in these fossil spicules are considerably enlarged, and they contrast strongly with the very fine, oftentimes scarcely visible, axial canals in the spicules of recent sponges. In some instances the silica of the interior of the spicules has been dissolved away to such an extent that only a thin outer sheath of the original wall remains. The enlarged canals have usually smooth and even walls, but not infrequently they are eroded irregularly and have a nodose appearance. The outer surface of the spicules is very commonly covered with small circular pittings and their walls are bored at right angles with neat cylindrical holes which often penetrate to the axial canal of the spicule. Similar borings and enlarged canals are found in detached sponge spicules dredged up from considerable depths and they have been attributed to the action of boring algæ (1).

Comparatively few of the larger spicules in this soft rock are preserved intact ; a large proportion are broken up into small fragments. The larger and more robust monaxon spicules, together with the trifids and calthrops have suffered most from fracture, and uninjured specimens are difficult to find, whilst many of the smaller fusiform, cylindrical, pinshaped, and styliform spicules and the delicate dermal spicules of lithistid sponges, remain in a perfect condition. The skeletal spicules of lithistids have, as a rule, lost their distal ends, by which they are interlocked together. The robust meshwork of dictyonine hexactinellids, which might have been supposed strong enough to resist fracture, is in the material, now reduced to microscopic fragments.

On the whole the preservation of the sponge spicules in this Norseman material is very similar to that of other fossil sponge deposits of Tertiary Age, and it does not markedly differ from that of the detached spicules found at the present time of the sea floor.

DESCRIPTION OF THE SPONGE SPICULES.

With the view of correlating the spicules in this Norseman material with those in similar fossil deposits in other regions, and also with those of recent siliceous sponges, the various forms commingled together in the rock sample are described and figured below. The similar forms of Monaxonid spicules are first considered and afterwards those of Tetractinellid, Lithistid and Hexactinellid Sponges.

Monaxonid Spicules.

The fusiform acerate, cylindrical, styliform, dumb-bell or tibiella and pin-shaped spicules with a single axis are very numerous. With the exception that a few of the larger acerate spicules belong to the Tetractinellida, the rest are the skeleton spicules of the Monaxonida. The very minute so-called flesh spicules are poorly

(1.) Duncan. Journ. Roy. Micros. Soc., ser. 2, Vol. I. (1881), p. 557, pls. VII., VIII.

represented in the deposit by a few forms of chessman or sceptrella spicules belonging to the genus *Latrunculia*.

No anchorate flesh spicules have been observed in the deposit.

Acerate Skeleton Spicules of various genera.

Pl. I., fig. 1.—Fusiform acerate, robust, smooth, slightly curved, greatest thickness in the centre ; tapering gradually to each end. Length 1·5 mm., thickness (1) 0·07. Probably belongs to a species of *Geodia*.

Pl. I., fig. 2.—Fusiform acerate with tapering drawn out ends, smooth. Length 0·43 by 0·05. Common. An axial canal is not shown in these spicules. A spicule very similar in form and proportions occurs in *Desmacidon* (*Homœodictya*) *grandis*, from Simon's Bay, Cape of Good Hope. Ridley and Dendy (Chall. Rep., vol. 20, p. iii, pl. XXIX., fig. 7).

Pl. I., fig. 3.—Fusiform acerate, slightly curved, gradually tapering to both ends which are acutely pointed. It is very similar to the spicules of a variety of *Petrosia variabilis*, Ridley. (Chall. Rep., vol. XX., p. 13, pl. II., fig 12). Length 0·43 by 0·03.

Pl. I., fig. 4.—Fusiform acerate, very evenly curved, the ends blunted, smooth. An axial canal is not recognizable in the specimen figured. Length 0·38 by 0·03. Common.

Pl. I., fig. 5.—Robust fusiform acerate, bent near the centre, tapering towards the ends, which are slightly blunted, smooth. Length 0·33 by 0·035.

Pl. I., fig. 6.—Robust vermiculate spicule, curved and undulating ; surface smooth. The axial canal opens at both ends, which are blunted. Length 0·68, thickness 0·064. Rare.

Pl. I., fig. 7. - Acerate, straight or slightly curved, tapering near the ends, which are blunted; the surface is covered with minute conical spines. Length 0·22 by 0·03. Smaller but similarly spined spicules are present in the sponge deposits at Oamaru, New Zealand (Linn. Soc. Jour. Zool., vol. XXIV., p. 184, pl. VII., fig. 15), and in the recent *Halichondria infrequens*. Carter, from the Gulf of Manaar (Ann. and Mag. Nat. His. s. 5, vol. VII., 1881, p. 369, pl. XVIII., fig. 9*a*.)

Cylindrical Spicules of various genera.

Pl. I., figs. 8, 9.—Slightly curved cylindrical spicules, smooth, with ends evenly rounded. As a rule no axial canals are shown in these forms; they vary greatly in size, the larger range to 0·46 by 0·06, the smaller are nearly reniform and about 0·08 by 0·03. The specimens are numerous and well preserved. Similar spicules are present in the Oamaru deposit (*op. cit.*, p. 184, pl. VII., figs. 31, 36), and also in the material dredged by the "Egeria" from a depth

(1.) The dimensions of the spicules are in all cases given in millimeters and decimal parts thereof, it is proposed therefore to omit "mm." after each measurement.

of 3,001 fathoms off the South-West coast of Australia. *Strongylophora durissima*, Dendy, from the Gulf of Manaar, is built up of similar spicules of various sizes. (Supp. Rep. Pearl Oyster Fisheries, Gulf of Manaar, p. 141, pl. IX., fig. 1.)

Pl. I., fig. 10.—Curved cylindrical spicule, with evenly rounded non-inflated ends, the surface with slightly raised whorls or rings with the edges minutely spined. Length 0·29 by 0·025. Smaller spicules similarly spined occur in the Oamaru material (op. cit., pl. VII., figs. 29, 30), and Mr. Carter has figured a detached spicule of the same kind from the Gulf of Manaar (Ann. and Mag. N.H., ser. 5, vol. VI., 1880, pl. V., fig. 29). The sponge to which these belong is unknown.

Pl. I., fig. 11.—Robust, straight, cylindrical, spicule with round, spined ends, the lateral surface with stout blunt spines disposed in whorls. Length 0·25 by 0·085. Approximately similar spicules, but with the spines not so regularly arranged, are present in the Oamaru material (*op. cit.*, p. 187, pl. VII., figs. 42, 43).

Pl. I., fig. 12.—Subcylindrical spicule with a prominent acute spine at each end, and the lateral surfaces armed with whorls of alternate larger and smaller spines. Length 0·2 by 0·09 in width, spines included. Similar spicules are present in material dredged by the "Egeria," lat. 36° 53′ S., long. 115° 48′ E., depth 3,001 fathoms. Sponge unknown.

Pl. I., fig. 13.—Subcylindrical, slightly curved, with a prominent spine at each end, lateral surface with whorls of subequal spines. Length 0·28 by 0·08.

Tibiella or Dumb-bell Spicules.

Pl. I., fig. 14.—Slightly curved tibiella, shaft fusiform with sub-spherical ends, smooth. Length 0·17 by 0·015.

Pl. I., fig. 15.—Tibiella nearly straight, the shaft cylindrical with a round knob at each end, smooth. Length 0·37, thickness of shaft 0·02, of terminals 0·03. Similar but somewhat smaller spicules are described by Carter in *Forcepia crassanchorata* from Port Elliot, South Australia (Ann. & Mag. N.H., s. 5, vol. XV., 1885, p. 111, pl. IV., fig. 3*b*).

Pl. I., fig. 16.—Tibiella, slender, curved, shaft cylindrical with spherical ends, smooth. Length 0·1 by 0·005, terminals 0·007. Rare.

Sceptrella or Chessman Flesh Spicules of LATRUNCULIA, Bocage.

Pl. I., fig. 17.—Sceptrella with a relatively stout axis, the base expanded with small divergent spines, a median disc armed with short spines and a cupolar summit, also spined. Height, 0·07, thickness of shaft 0·017, width of median disc 0·05. Rare.

Pl. I., fig. 18.—Sceptrella small, with stout axis, base expanded with a thin spined edge supported on a fringe of acute spines

extending obliquely downwards ; a thin median disc with sharp edge ; the summit convex, smooth, with a sharp margin. Height 0·055, breadth of base and summit 0·045.

Pl. I., fig. 19.—Sceptrella with a slightly expanded and arched base with downward projecting spines ; in the middle of the shaft a whorl of horizontal spines ; the summit with a marginal fringe of spines and a prominent vertical spine. Height 0·066, width of axis 0·066 ; of the central whorl 0·026. Rare.

Pl. I., fig. 20.—Sceptrella with a stout axis and an arched and spined base, a medium sharp edged disc ; the summit convex with vertical spines. Height 0·063, width of shaft 0·02, of the median disc and summit 0·036. Rare.

Pl. I., fig. 21.—Sceptrella relatively small, the basal portion and median disc similar to the preceding in form, the summit like truncated cone with minute spines. Height 0·04, width of shaft 0·011, of median disc 0·026. Rare.

Pl. I., fig. 22.—Sceptrella with slender cylindrical shaft and a small median disc with smooth margin, the summit slightly expanded with the margin notched. Length 0·05, width of shaft 0·006, of median disc 0·02.

Four of the forms of Sceptrella described above (pl. I., figs. 17, 18, 20, 21) are modifications of a common type which has an expanded base with divergent spines, a median disc and a convex summit : in fig. 19 there is a median whorl of spines and at the summit a prominent spike, whilst in fig. 22, there is no distinctive base, a small median disc and a notched summit. Each of these forms may represent a distinct species of *Latrunculia*. Similar variations of form-details are shown in the Sceptrella spicules of the Oamaru deposit (op. cit. p. 215, pl. XI., figs. 15–39).

Style or Acuate Spicules.

Pl. I., fig. 23.—Part of an elongated tapering spicule, probably a style similar to those in the genus *Tethya*, Lam. The part preserved is 1·64 in length by 0·04 in thickness at the fractured end.

Pl. I., fig. 24.—Style, robust, smooth, slightly curved at the proximal end, and tapering in the lower third of the spicule. Length 0·72 by 0·04. Similar skeleton spicules are present in the recent *Myxilla hastata*, Ridley and Dendy, from off the mouth of the Rio de la Plata at 600 fathoms. (Chall. Rep. vol. 20, p. 134, pl. XXVII., fig. 1). Common.

Pl. I., fig. 25.—Style slender, slightly curved, nearly of an even thickness throughout. Imperfect at the distal end. Length 0·73 by 0·02. Rare.

Pl. I., fig. 26.—Style slender, elongate, smooth, the summit evenly rounded and curved nearly at right angles to the straight.

gradually tapering shaft. Length 0·37 by 0·017. A similar but somewhat more robust spicule occurs in the Oamaru material (*op. cit.*, p. 191, pl. VIII., fig. 30).

Pl. I., fig. 29.—Nearly straight, robust style, the upper third stout, then somewhat rapidly tapering to the apex. The upper portion of the spicule is covered with minute conical spines, the lower two-thirds is quite smooth. Length 0·39, maximum thickness 0·06. Rare.

Spinulate or Pin-shaped Spicules.

Pl. I., fig. 27.—Robust spinulate slightly curved, head spherical, constricted at the neck, shaft slightly increasing in thickness towards the middle, the lower portion of the spicule is wanting. Length (incomplete) 0·57 by 0·05.

Pl. I., fig. 28.—Straight, smooth spinulate, head spherical, neck slightly constricted, very gradually tapering to the apex. Axial canal normal. Length 0·42 by 0·02. A similar spicule is present in the Oamaru material (*op. cit.*, p. 193, pl. IX., fig. 6).

SPINES OF TETRACTINELLID SPONGES.

Calthrops Spicules.

Pl. I., fig. 30.—Robust calthrops, the rays sub-equal, smooth, gradually tapering. Length 0·28 by 0·06.

Calthrops spicules of various sizes are fairly common in the Norseman deposit, some are larger, others smaller than the specimen figured. They have in all cases, smooth, simple rays. Similar spicules are present in the Oamaru deposit (*op. cit.*, p. 231, pl. XIII., figs. 35–40) and in fossil sponge deposits generally.

Trifid Spicules of Geodia and other genera.

Pl. I., fig. 31.—Trifid with straight tapering shaft and simple head rays directed obliquely forwards. Length of shaft (incomplete) 0·34 by 0·05; head rays 0·16 by 0·04. It may be compared with the smaller trifid spicules of the Oamaru material (*op. cit.*, p. 234, pl. XIII., figs. 14, 15).

Pl. I., fig. 32.—Trifid with simple slightly curved and nearly horizontal head rays. The shaft is broken away just below the head, it is 0·035 in thickness: the rays are 0·08 in length. This spicule corresponds in form and size with the zone spicules of the recent *Stelletta reticulata*, Carter, from off the South coast of Australia (Ann. & Mag. N.H., ser. 5, vol. XI., 1883, p. 352, pl. XIV., fig. 46).

Pl. I., fig. 32.—Trifid, with simple, strongly curved head rays. Shaft (imperfect) 0·03 in thickness, head rays about 0·1 in length. It probably belongs to a species of *Geodia*. Similar spicules are found in the Oamaru material (*op. cit.*, p. 235, pl. XII., fig. 24),

and in deposit brought up by the "Egeria" off S.W. of Australia, lat. 36°·08′ S., long. 117°·10′ E., from a depth of 2,479 fathoms.

Pl. II., fig. 1.—Spicule with a tapering shaft and a single, slightly recurved head ray; the base of a second ray is shown, but there is no indication of a third. The shaft is 0·23 by 0·02, the head ray 0·037 in length. It appears to be an abnormal development of a trifid spicule.

Pl. II., fig. 2.—Trifid with straight elongate shaft and with each of the head rays bifurcated and horizontally extended. The tips of the rays are broken away, and the axial canal in the shaft is considerably enlarged. Shaft 0·36 by 0·03: width across the head rays 0·13. Similar spicules are present in the genus *Erylus*. Gray.

Pl. II., fig. 3.—Trifid with simple head rays directed upwards. The shaft (imperfect) is 0·04 in thickness, the head rays 0·12 by 0·02. Similar spicules occur in the recent genus *Craniella*, O. Schmidt and in *Stelletta* they are also present detached in the Oamaru material (op. cit. p. 234, pl. XIII., figs. 16, 17).

Pl. II., fig. 4.—Trifid spicule with a stout, straight shaft, and bifurcated head rays. The shaft is 0·05 in length. It may belong to *Erylus*. Gray. A form nearly similar is figured from Oamaru (op. cit. p. 234, pl. XIII., fig. 12).

Pl. II., fig. 5.—Trifid with curved tapering shaft and trifurcate head rays directed obliquely forwards. The head rays are partly broken, but in one the trifurcate character is distinctly shown by the axial canals. Shaft 0·37 by 0·05. The head rays are 0·14 in length.

Pl. II., fig. 6.—Trifid with slender shaft and simple head rays directed backwards. The shaft is 0·006 in thickness, the head rays are 0·05 in length and about the same thickness as the shaft. It may be compared with the grapnel spicules of *Cydonium Müller*i, Fleming—*Geodia Zetlandica*, Johnston (*see* Bowerbank, Mon. Brit. Spong. vol. III., pl. VII., fig. 7). Similar forms are common in the Oamaru material (*op. cit.*, p. 235, pl. XII., figs. 18–24).

Lithistid Spicules.

Body Spicules of Ragadinia, Zittel, *and* Discodermia, Bocage.

Pl. II., figs. 7, 8.—Spicules with four arms or rays; one is frequently truncated or reduced to a rounded knob; the fully developed arms have a prominent ring-like inflation a short distance from the spicular centre; beyond the ring the arms bifurcate and terminate in twig-like extensions which interlock with those of adjoining spicules. The delicate twig-like extremities are broken off the detached spicules. In one specimen (fig. 7), the axial canal is seen as a delicate straight line extending from the centre to about two-thirds the length of each arm; in the other (fig. 8), the canals are widened and reach to the ends of the arms, which are, however,

incomplete. The arms are about 0·17 in length, and 0·04 thick near the centre. The spicules belong to *Ragadinia*, Zitt. of which several species are known from the upper Cretaceous (*Bel. mucronata* Zone) of Germany and the South-West of England. Detached spicules closely resembling those from Norseman are known from Coesfeld in Westphalia, the Upper Chalk of Norfolk (1): also in the Upper Greensand near Warminster, Wiltshire, and in the Lower Greensand of Haslemere and Tilburstow Hill, Surrey (2).

Pl. II., figs. 9, 10.—Both the spicules figured are imperfect: in one (figure 9) an arm is wanting, and in the other (fig. 10) two are broken away, so that their original tetractadine character can hardly be recognised. Small extensions are given off from the arms; their ends are frequently furcate and they are covered with tubercles. In one (fig. 9), a delicate straight line in the principal arm may represent an axial canal whilst in the other (fig. 10), two short canals are shown near the broken margin. These spicules may belong to *Discodermia*, Bocage. Fragments of similar spicules are very common in the Norseman material.

Reniform and Globostellate Spicules of Tetractinellid Sponges.

Pl. II., figs. 12, 13.—Reniform spicules, similar to those forming the dermal crust of *Geodia* sponges, are very numerous in the deposit. Generally the hilum can be distinguished, but the minute rods with prominent heads of recent forms are not shown in these fossil specimens. Not infrequently they are perforated by boring algæ (?) as in the specimen figured (fig. 13). Small specimens measure 0·07 by 0·037, the larger 0·09 by 0·062.

Pl. II., fig. 14.—Globostellate spicules, apparently solid, their surfaces covered with short, stout, conical spines, which in some cases seem to be regularly disposed in lines. Diameter 0·1. Fairly numerous.

Pl. II., fig. 15.—Globostellate similar to the preceding, but much smaller. Diameter 0·04—0·05. Very common. Similar forms are present in the recent genus *Cydonium*, Muller.

Pl. II., figs. 16, 17.—Globostellate spicules with solid centra from which extend a number of stout cylindrical rays with expanded lobate summits. No canals are visible either in the rays or in the centra. Diameter 0·1. Similar spicules are present in the recent *Cydonium Müllerí* Fleming. They occur detached at Oamaru (op. cit. p. 237, pl. XIV., figs. 28, 29, 30, and also in the dredgings by the "Egeria" off the S.W. of Australia, from a depth of 2·479 fathoms.

Globostellate Spicules of TETHYA, Lamarck.

Pl. II., fig. 18.—Globostellate with numerous rays which originate in the centre of the spicule and for about one-third their length

(1.) Hinde. Fossil Sponge Spicules from the Upper Chalk of Horstead, 1880, p. 58, pl. 5, figs. 1–4.
(2.) Phil. Trans. Roy. Soc., vol. CLXXV., part II., 1885, p. 444, pl. XLV., figs. 5, 5a, 5b.

extend beyond the centrum. The rays are straight and the free portions gradually taper. In each there is a well-marked, now enlarged, canal, which begins at the origin of the ray and opens at its free distal end. The figured specimen is 0·13 in diameter: smaller forms are about 0·08, including the rays. These spicules are closely related to those of *Tethya robusta*, Bowerbank (Proc. Zool. Soc. Lond., 1873, p. 10. pl. II., fig. 15) now living in Australian seas. They are very common in the Norseman material, but as a rule the free portions of the rays are broken off. Similar detached forms are present in the Upper Cretaceous (Zone of *Bel. mucronata*) of Westphalia, and in the same zone of the Chalk of Norfolk.

Pl. II., fig. 19.—Small globostellate with 12–14 acutely pointed rays extending for about half their length beyond the centrum. No canals visible. Diameter, including rays, 0·05. This form may be one of the smaller stellates of the crust of a species of *Tethya*.

Dermal Spicules of Lithistid Sponges,

Pl. II., figs. 20, 21.—Spicules consisting of a thin, flattened siliceous plate with very irregular lobate margins. In the centre of the plate is a short, acutely pointed shaft which projects at right angles from the inner or lower surface. Three short canals radiate from the junction of the shaft with the plate and in the central point is a small circle representing the axial canal of the shaft. The shaft in these spicules is usually broken off the horizontal plate. The plate or head of these spicules is about 0·3 in breadth. The sponge to which they belonged cannot be known with certainty; they may have formed the dermal layer of a species of *Ragadinia* whose skeleton spicules have been described above.

Dermal Spicules of Discodermia, Bocage.

Pl. II., fig. 22.—The spicule figured has the margins rounded, but in other specimens of the same form they are irregularly lobate. The outer surface has numerous minute spines or papillæ, as Carter terms them, and these are connected with each other by delicate raised lines which give the appearance under the microscope of a fine network with polygonal meshes. Three short axial canals are shown in the centre of the spicule. The spicular heads are 0·3–0·38 in breadth. The shafts are wanting. The late Mr. Carter has described dermal spicules with a similar surface network in the recent *Discodermia aspera* from the Gulf of Manaar (Ann. & Mag. N.H., ser. 5, vol. VI., 1880, p. 501, pl. VIII., fig. 49*g*), but in a microscopic slide of the spicules of this sponge, mounted by himself and presented to me, there is no net-work shown on the dermal spicules, nor does Prof. Sollas mention this character in describing *D. aspera* though he studied the spicules in a slide also supplied to him by Mr. Carter (Chall. Rep. vol. XXV., p. 327). It is probable therefore that the dermal spicules with this peculiar and distinctly marked surface ornamentation may belong to some other species than

D. aspera. The detached forms in the Norseman material are very common, and well preserved as a rule.

Pl. II., figs. 26–26.—Dermal spicules with an elongate slender shaft and a saucer-shaped or vasiform expansion at its summit. The expanded head is approximately circular in outline, the margins are smooth, even and slightly elevated (fig. 25) ; in the centre is a small boss or knob which in some cases may project above the level of the margins (fig. 23), in others it is hardly perceptible (fig. 24). Viewed from below, the under surface of the spicule shows one or more concentric growth lines and faint traces of radiating folds reaching a short distance above the edge ; the fractured summit of the shaft and its axial canal are shown in the centre (fig. 26). The axial canal of the shaft is closed at or just below the junction of the shaft and the head, it extends the length of the shaft and opens at its distal apex. There is no indication of canals radiating from the centre in any of these spicular heads. In one specimen the shaft is embraced by a portion of a skeleton spicule of the sponge to which the dermal spicule belonged. The shaft is about 0·2 in length : the expanded heads are 0·075–0·11 in breadth. They belong to a species of *Discodermia* not improbably to the same form as the skeleton spicules described above (pl. II., figs. 9, 10).

Nearly similar dermal spicules are figured by O. Schmidt (1) in *D. dissoluta* from off Barbados at a depth of 56 fathoms : by Carter (2) in *D. lævidiscus* from the Gulf of Manaar, and by Sollas (3) in *D. ornata* a recent sponge of unknown locality. As the Norseman spicules differ in smaller details from those in the species just mentioned, it is probable that they belong to a sponge yet undescribed.

Dermal Spicules of CORALLISTES, O. Schmidt, *and other genera.*

Pl. III., fig. 1.—Dermal spicule with a short shaft and at its summit six horizontally extended rays. The rays are sub-equal when complete and they are traversed by axial canals which extend to the distal ends of the rays. The rays are about 0·18 in length by 0·05 wide. The head of the specimen is 0·39 across. These spicules are common in the Norseman material but generally in fragments. Similar detached spicules are found in the Oamaru deposit, also in the material dredged by the "Egeria" off the S.W. of Australia from a depth of 2,479 fathoms. They also form the dermal layer in several genera of Megamarine and Tetracladine Sponges from the Upper Cretaceous of the South of England and of Germany, and in the recent genus *Corallistes*, O. Schmidt.

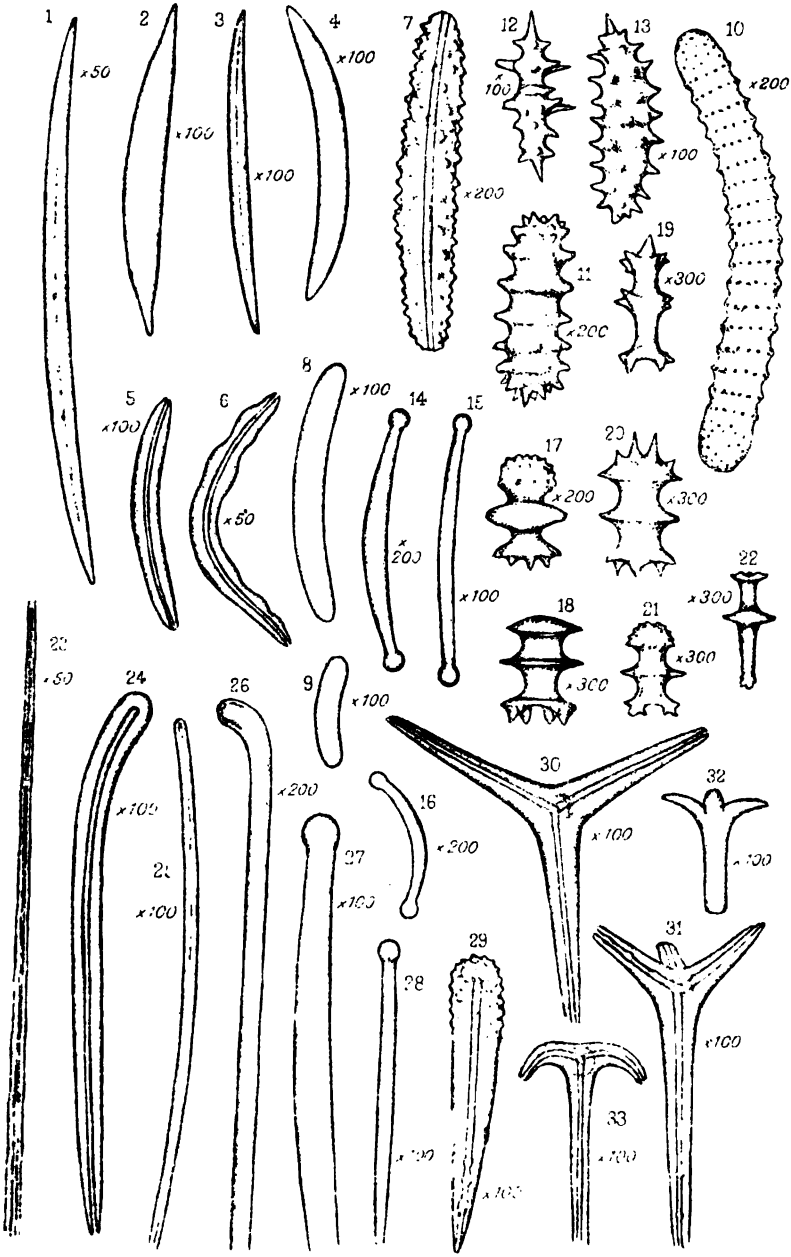
Pl. III., fig. 2.—Dermal spicule with a short shaft and five horizontally extended rays at its summit. In this form one of the head rays of the normal trifid remains simple, and the other two

(1.) Die Spongien des Meerbusen von Mexico, Heft. II., 1880, p. 87, pl. V., fig. 2c.
(2.) Ann. & Mag., N. H., ser. 5, vol. VI., 1880, p. 503, pl. VIII., figs. 51c, d.
(3.) Chall. Rep. vol. XXV., p. 297, pl. XXXI., figs. 5, 5a, 5d.

EXPLANATION OF PLATES.

Plate I.

Fig. 1.—Acerate spicule. Probably of *Geodia*—× 50.
„ 2.—Acerate spicule of *Desmacidon* (?)—× 100.
„ 3.—Acerate spicule of *Petrosia* (?)—× 100.
Figs. 4, 5.—Fusiform acerate spicules—× 100.
Fig. 6.—Vermiculate spicule—× 50.
„ 7.—Spined acerate of *Halichondria* (?) × 200.
Figs 8, 9.—Smooth cylindrical spicules of *Strongylophora* (?)—× 100.
Fig. 10.—Curved cylindrical spicule with spined whorls—× 200.
„ 11.—Straight cylindrical spicule with whorls of spines—× 200.
„ 12.—Subcylindrical spicule with whorls of spines—× 100.
„ 13.—Curved cylindrical spicule with whorls of spines—× 100.
„ 14.—Curved tibiella or dumb-bell spicule—× 200.
„ 15.—Straight tibiella of *Forcepia* (?)—× 100.
„ 16.—Curved tibiella spicule—× 200.
„ 17.—Sceptrella spicule of *Latrunculia* sp.—× 200.
„ 18.—Sceptrella spicule with smooth convex summit, *Latrunculia*—× 300.
„ 19.—Sceptrella spicule with median whorl of spines, *Latrunculia* sp.—× 300.
„ 20.—Sceptrella spicule with convex spined summit, *Latrunculia* sp.—× 300.
„ 21.—Sceptrella spicule of *Latrunculia* sp.—× 300.
„ 22.—Sceptrella spicule with cylindrical axis, *Latrunculia* sp.—× 300.
„ 23.—Style spicule of *Tethya* (?) distal portion—× 50.
„ 24.—Style spicule of *Myxilla* (?) sp.—× 100.
„ 25.—Style spicule (imperfect)—× 100.
„ 26.—Style spicule with curved summit—× 200.
„ 27.—Spinulate spicule (imperfect at the distal end)—× 100.
„ 28. Pin-shaped spicule—× 100.
„ 29.—Style with the upper portion spined, the lower smooth—× 100.
„ 30.—Calthrops spicule with subequal rays—× 100.
„ 31.—Trifid spicule with simple head-rays—× 100.
„ 32.—Trifid spicule (upper portion) of *Stelletta* sp.—× 100.
„ 33.—Trifid spicule of *Geodia* (?) with recurved head-rays—× 100.

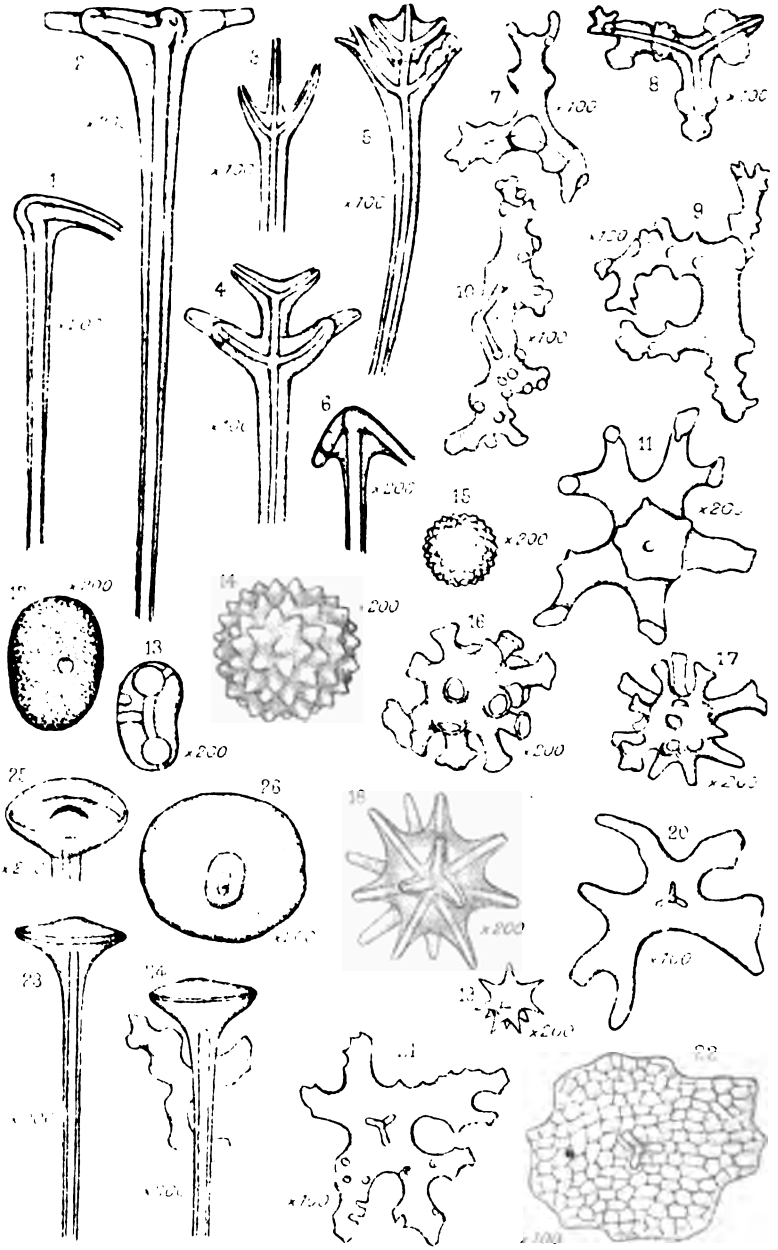


West, Newman & Co. imp.

FOSSIL SPONGE SPICULES, NORSEMAN, W. AUSTRALIA

Geology Gen. Survey

Plate II.



Bulletin No. 36.
Coal Seams of N.S.W.

West Newman, Litho.

DEPT. MINING. SPECIMENS OF COAL FROM NEW SOUTH WALES.

Plate 11.

Fig. 1.—Trifid spicule, abnormal, with only two head-rays—× 200.
„ 2.—Trifid spicule with bifuracted head-rays—× 200.
„ 3.—Trifid spicule of *Craniella* (?) sp. (upper portion)—× 100.
„ 4.—Trifid spicule of *Erylus* (?) sp. (shaft imperfect)—× 100.
„ 5.—Trifid spicule with head rays trifurcate—× 100.
„ 6.—Trifid spicule of *Cydonium* (?)—× 200.
Figs. 7, 8.—Skeleton spicules of *Ragadinia* sp.—× 100.
„ 9, 10.—Skeleton spicules, imperfect, of *Discodermia* sp.—× 100.
Fig. 11.—Skeleton spicules of *Vetulina* sp.—× 200.
Figs. 12, 13.—Reniform spicules of *Geodia*. Fig. 13 shows perforations of boring alga—× 200.
Fig. 14.—Globostellate spicule—× 200.
„ 15.—Globostellate spicule of *Cydonium*—× 200.
Figs. 16, 17.—Globostellate spicule of *Cydonium* sp.—× 200.
Fig. 18.—Globostellate spicule of *Tethya* sp —× 200.
„ 19.—Globostellate spicule of *Tethya* sp.—× 200.
Figs. 20, 21.—Dermal spicules of *Ragadinia* sp.—× 100.
Fig. 22.—Dermal spicules of *Discodermia* showing surface network.—× 100.
Figs. 23–26.—Dermal spicules of *Discodermia* sp. Fig 23 is a lateral view, showing the shaft and a prominent boss in the centre of the head plate. Fig. 24 is a specimen with a portion of a skeleton spicule entangled round the shaft. Fig 25 shows the upper surface of the head plate, and Fig. 26 shows the under surface with the broken stump of the shaft—all × 200.

Plate III.

Fig. 1.—Dermal spicule of *Corallistes* (?)—× 100.

„ 2.—Dermal spicule showing the head-rays (?) *Theonella*—× 100.

„ 3.—Dermal spicule with the head-rays unequally developed—× 100.

Figs. 4, 5.—Dermal (?) spicules of unknown sponge. *Dactylocalycites* Carter. The lower margin of Fig. 4 is partly broken away—× 200.

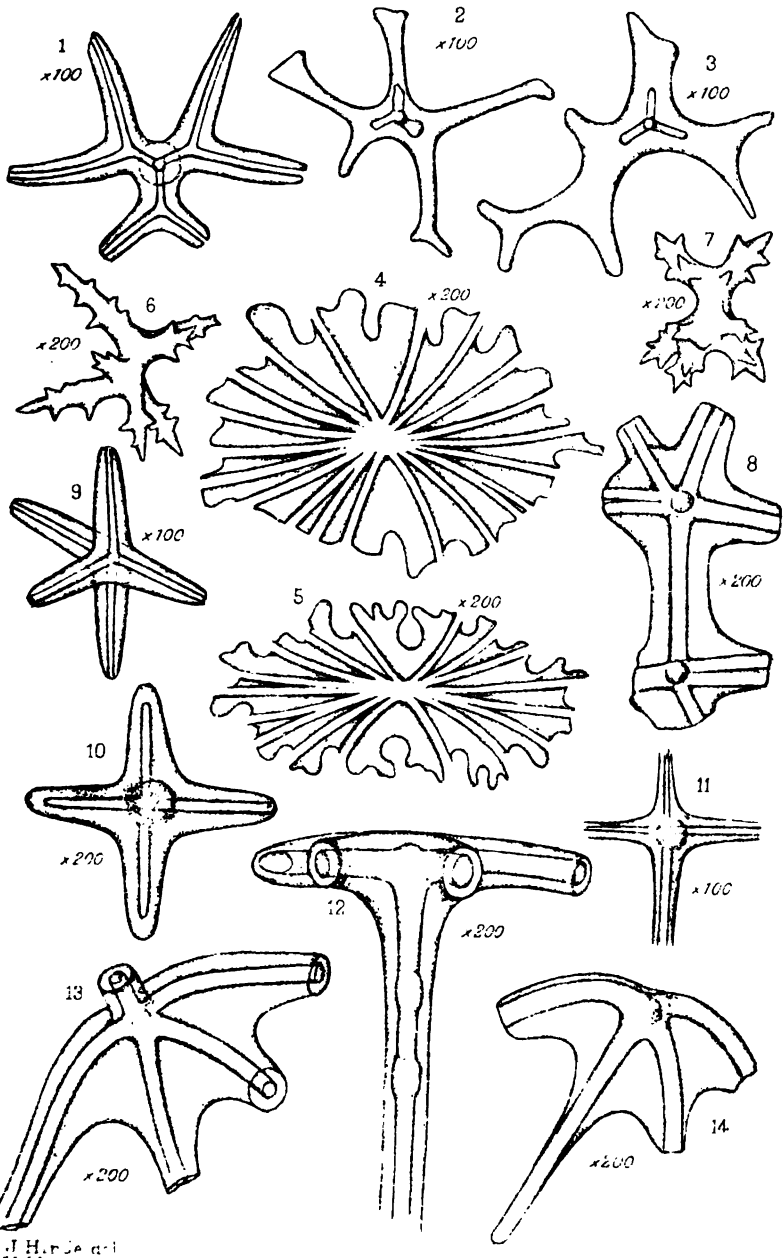
„ 6, 7.—Spicules with spinous rays. Sponge unknown—× 200.

Fig. 8.—Fragment of spicular framework of dictyonine hexactinellid—× 200.

Figs. 9, 10, 11.—Detached five-rayed spicules of hexactinellid sponges. Figs. 9 and 11—× 100; Fig. 10—× 200.

„ 12, 13, 14.—Umbrella spicules of the dermal surface of *Rossella* sp. all fragmentary. Fig. 12 gives a lateral view of the upper portion of the vertical shaft and of the basal portion of the four horizontal rays which radiate from its summit. Figs. 13 and 14 represent the proximal portion of the four horizontal rays with their canals and the patagium connecting the rays; also the broken summit of the vertical shaft—× 200.

The spicules figured on the plates were all derived from a specimen of siliceous rock from the Deep Lead (?) at Princess Royal, Norseman District, Western Australia.



J. H. Ride del.
G. H. Woodward lith.
West, Newman, imp.

FOSSIL SPONGE SPICULES, NORTH NEW SOUTH WALES.

II.—*Some Fossil Plants from Western Australia.*

BY

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The specimens submitted to me were derived from two localities.

The first of these was Mt. Hill (second hill about half mile from Trig. Station) and is represented by two specimens numbered [**8050**] and [**8054**] respectively.

Specimen [**8050**] (3 pieces) is a portion of a coniferous trunk, in which the structure is in part preserved. A transverse section has been made of the specimen, but the preservation of the wood, on microscopic examination, proved to be far too imperfect to permit even of generic determination. It is impossible to determine the age of the beds from which it was derived.

Specimen [**8054**] (2 pieces) has been cut across, and appears to be an arenaceous (?) rock containing a number of thin, eroded fragments or chips of wood, the structure of which is, for the most part, not preserved. Here and there, however, fragments of the wood appear to be petrified, but not sufficiently to permit of determination. The specimen affords no indication of the age of the beds from which it was derived. It is, however, probably *not* Palæozoic.

The second locality was the main road on West boundary of M. 299, 28 chains South of the North-West corner, about three miles South of Mingenew. Altitude about 500 feet above Mingenew. 25 specimens, numbered [**8104 A-Y**], were forwarded to me from this locality.

Otozamites Feistmanteli, *Zigno.*

1881—*Otozamites Feistmanteli*, Zigno, Flora. Foss. Oolit, Vol. II., p. 90, pl. 34, figs. 6-8.

1900—*Otozamites Feistmanteli*, Seward, Jurassic Flora (Brit. Mus. Catal.) Vol. I., p. 221.

1907—*Otozamites Feistmanteli*, Salfeld, Palæontogr., Vol. 54, p. 182, pl. XIX., fig. 14.

This fossil frond is represented by 15 specimens [**8104, A-O**], each exhibiting one or more examples.

The fronds vary considerably in detail, both as regards the shape of the leaflets and the degree of imbrication. There is, however, every reason to believe that they all belong to the same species.

[8104, D.] is a good example of one type, in which the pinnules are short and overlap one another. The shape and nervation of the pinnules is well seen. They are attached to the upper surface of the rachis by a broad base, the upper angle of the base being auriculate. This frond appears to be quite identical with that figured by Zigno (*see* above) on fig. 8 of plate 34, from the Lower Jurassic of Italy. This species has also been determined from the Lower Oolite of Britain.

The fronds seen on specimens **[8104 A, B, C, G, I, J,** and **K]** are similar to **[8104 D]** ; the nervation being well seen in **[8104 C]**.

In **[8104 F]**, also **[8104 E** and **L]**, the pinnules are more elongate, their length being about 2 c.m. as compared with 1·3–1·4 c.m., in the case of **[8104 D]**.

In **[8104 M]** the base of a small frond is seen where some of the pinnules do not exceed 3 m.m. in length, and are more oval in shape.

In **[8104 H]**, the pinnules are less imbricated, and this feature is also seen in **[8104 L]**, which shows two fronds, one with short, imbricated pinnules similar to **[8104 D]**, and another larger frond with longer pinnules, more distant from each other.

In **[8104 N–O]** the pinnules are also less imbricated.

A comparison of the typical specimen **[8104 D]** with the figure given by Kurr of his *Zamites Mandelslohi* (Beitr. foss. Flora Jura format., Württembergs, 1845, p. 10, pl. I., fig. 3), would appear to indicate that the Australian frond may be identical with that occurring in the Lower Oolite of Germany. On the other hand, this matter remains in doubt, for the specimens recently figured under this name, from the Lias of Holzmaden, Württemberg, by Salfeld (Palæontogr., Vol. LIV., 1907, p. 182, pl. XVI., figs. 1*a*, 1*b*, 1*c*) do not appear to be specifically identical with the Australian leaves.

Feistmantel (Mem. Geol. Surv. New South Wales, Pal. No. 3, 1890, p. 147, pl. 28, figs. 9, 9*a* ; refigured by Salfeld, *ibid*, pl. XIX, fig. 14 ; *see* also Jack and Etheridge Geol. and Palæontol. of Queensland 1892, p. 381) has also compared a Queensland fossil, from the Talgai coalfield on the Condamine River, with *Otozamites Mandelslohi* (Kurr). Feistmantel's figure, however, appears to be rather carelessly drawn, or else the specimen is not very well preserved.

There would appear to be a distinct possibility that his frond from Queensland may be identical with the fossils under discussion here, but until his figured specimen (in the Min. and Geol. Mus., Sydney) has been compared with the West Australian leaves, it will be difficult to form any opinion on this point.

So far as I am aware Feistmantel's record is the only species of *Otozamites* as yet found in Australia, though Tenison-Woods

(Proc. Linn. Soc. New South Wales, 1883, vol. VIII., p. 151) has described the same species from another locality in Queensland, *i.e.*, the Darling Downs near Toowoomba.

Thus while there may be some uncertainty as to the identity of the Australian fossils with Kurr's species *Otozamites Mandeslohi*, there is every reason to regard them as specifically identical with the *O. Feistmanteli*, Zigno, of the lower Jurassic of Italy and England. Professor Seward (*ibid.* p. 221) has diagnosed this specie as follows:—"Frond narrow, linear; pinnæ short and broad, attached to the upper face of the rachis by a broad base, of which the upper corner is slightly auriculate; the apex is bluntly rounded, the tip being directed upwards. Venation of the *Otozamites* type."

cf. PAGIOPHYLLUM. *sp.*

[8104 X–Y]. A portion of a Gymnospermous twig occurs on this specimen associated with a frond of *Otozamites Feistmanteli*, Zigno. The preservation is unfortunately very poor, and it is not possible to determine even the genus with certainty. It appears to stand nearest to the genus *Pagiophyllum*, and with it may be compared the *Pagiophyllum Kurri* of Schimper from the Lias of Germany (*see* Salfeld, *ante*, p. 186, pl. XIX., fig. 1: also the *Araucaria peregrina* of Kurr, *ante*, p. 9. pl. I., fig. 1). Tenison-Woods has figured (*ante* p. 165, pl. 4, fig. 1) an obscure specimen under the name *Cunninghamites Australis*, sp. nov., which may also be compared with this fossil. Tennison-Wood's specimen was obtained from the Mesozoic beds of Rosewood, Ipswich, Queensland.

FOSSIL WOODS,

[8104 P, Q, S, T, U.] Fragments and casts of fossil stems, in which the structure is not preserved. They are indeterminable, and of no value. The ribbed specimen **[8104 U]** has been cut across, but it is obviously not petrified, and consequently no sections were made of it. It is probably not the pith cast of an Equisetaceous genus, but of Coniferous origin. **[8104 T]** shows what may possibly be a ribbed pith cast, and part of the wood lying more externally. It is, however, impossible to determine its position in the Vegetable Kingdom. **[8104 R]** is a poor cast of a branching or leafy twig, and is also indeterminable.

INDETERMINABLE.

[8104 V–W]. A minute fragment of what appears to be the apical portion of the pinna of a frond. Each pinnule appears to possess a well marked mid-rib, but otherwise the nervation is not seen. The specimen is far too fragmentary and badly preserved to be determinable.

[8104 W] also shows two small seed-like bodies, which are indeterminable.

Conclusions as to the Age of the Beds in the Second Locality.

Of the specimens examined, the fronds of *Otozamites Feistmanteli*, Zigno, and the specimen compared with *Pagiophyllum*, alone afford any evidence as to the age of the beds.

These plants occur in the Jurassic of Europe, and possibly also in (?) Jurassic beds in Queensland. So far as a comparison with the European fossils is concerned, the age would appear to be *earlier* rather than *later* Jurassic. *O. Feistmanteli*, Zigno, occurs in the Lower Jurassic of England and Italy, and possibly also in Germany. *Pagiophyllum Kurri*, with which [**8104 X–Y**] may be compared, is a Lower Jurassic fossil from Germany. As regards the plant bearing beds elsewhere in Australia, the flora of beds, probably of Jurassic age, in Queensland at Talgai (Condamine River), the Darling Downs, and Rosewood, West of Rockhampton, affords the closest comparison with the specimens from Western Australia.

III.—Oolitic Fossils of the Greenough River District, Western Australia,

BY

R. ETHERIDGE,

Curator of the Australian Museum, Sydney, N.S.W.

I.—Introduction.

Through the kindness of Mr. A. Gibb Maitland, Government Geologist, I have lately had the pleasure of examining a collection of the Oolitic fossils of the Greenough River District.

The principal, and really only important, paper dealing with West Australian Mesozoic fossils, up to a comparatively recent date, was that of the late Charles Moore * of Bath, England. He enumerated a large number of species occurring in that State and of these he described or figured eleven ; nine were described as new, and twenty were believed to be identical with European species. I am now in a position to figure some of these exotic forms mentioned by Moore. In 1904, Mr. F. Chapman published a paper dealing with West Australian Jurassic fossils in the National Museum, Melbourne, † but no new forms were described.

II.—Description of the Species.

CLASS ANNELIDA.

Genus Serpula, *Linnæus*, 1758.
(Systema, Ed. X., p. 786).

Serpula conformis, *Goldfuss.*
(Plate IV., Fig. 1.)

Serpula conformis, Goldfuss, Petrefacta Germaniæ, 2nd Edit., 1862. I., p. 212, pl. 67, f. 13, *a* and *b*.

Obs.—A few small *Serpulæ* are attached to the surfaces of Mollusca. There is no feature to distinguish them from the above carinate Oolitic species.

Moore enumerated *Serpulæ* but without attaching specific names.

Loc.—Tibraddon Station, Greenough River.

* Moore—Quart. Journ. Geol. Soc., 1870, XXVI., pp. 228–261, pls.
† Chapman—Proc. R. Soc., Vict., 1904, XVI., (n.s.), p. 327.

CLASS BRACHIOPODA.

GENUS RHYCHONELLA, *Fischer*, 1809.
(Notice Foss. Gouv. Moscou, p. 35.)

RHYNCHONELLA VARIABILIS, *Schlotheim*.
(Plate IX., Figs. 3 and 6).

Rhychonella variabilis (Schlotheim), Davidson, Mon. Brit. Oolitic and Liassic Brach., 1852, pt. 3, p. 78 (for synonomy), pl. 15, f. 8–10, pl. 16, f. 1–6.

Obs.—This species was first recorded by Mr. Moore.* In the present collection are biplicate and triplicate individuals, answering to the varities *bidens* and *triplicata* of Phillips.

Loc.—Snake Farm, Greenough River.

CLASS PELECYPODA.

GENUS OSTREA, *Linnæus*, 1758.
(Systema, Ed. X., p. 696).

OSTREA THOLIFORMIS, † *sp. nov.*
(Plate VII., Figs. 2–7.)

Sp. Chars.—Lower valve obtusely conical, irregularly low-dome or cupola-shaped, with a large concave scar of attachment: test very thick. Upper valve flat, a little concave, or the surface rolling. Cardinal margin in both valves well developed, extending the entire width of the upper valve; chondrophore comparatively large; resilium furrows both in the chondrophore and on cardinal margin are strong. Adductor scar in the upper valve oblique and transversely ovate, with exsert lower margin. Well developed latilaminæ on the exterior of both valves.

Obs.—There are ten examples of this oyster in the collection. It is a solid and substantial, although not large form; one specimen is sub-lobate, the others irregularly round, or oval, in marginal outline. It may possibly belong to one of Bayle's sections of the Genus *Pycnodonta* or *Rhynchostreon*. In the works and collections at my command I am unable to find any species precisely like it but the nearest is *O. akkabensis*, Krumbeck,‡ from the Syrian "Glandarienkalk."

A second species of oyster is possibly present (Pl. IX., fig. 2). It is an upper valve, flat and deltoid in outline, not unlike the same valve of the Kimmeridgian *O. deltoidea*, Sby., but rather less deltoid.

Loc.—Tibraddon and Sandspring Stations, Snake Farm, Greenough River; Fossil Hill, two miles East of Moonyeenocka Railway Station.

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* Moore—Quart. Journ. Geol. Soc., 1870, XXVI., pp. 231, 232, pl. 10, f. 11 and 12.
† *Tholus*—a dome or cupola.
‡ Krumbeck—Beitrage Pal. Geol. Oster.—Ung. Orients, 1905, XVIII., Heft 1 and 2, pl. 12, f. 1 and 2.

GENUS ALECTRYONIA, *Fischer*, 1806.
(Bull. Soc. Imp. Nat. Moscou, VIII.)

ALECTRYONIA MARSHII, *J. Sby., sp.*
(Plate IV., Figs. 5–7 ; Pl. V., Fig. 4).

Ostrea diluviana, Parkinson, Organic Remains, etc., 1811, III., p. 217, pl. 15, f. 1.

Ostrea Marshii, J. Sowerby, Min. Conchol., 1816, I., p. 103, pl. 48.

Ostrea Marshii, Goldfuss, Petrefacta Germaniæ, 1833, II., lief. 4, pl. 73.

Ostrea Marshii, Morris and Lycett, Mon. Moll. Gt. Oolite, 1854, pt. 3, p. 126, pl. 14, f. 2, 2*a*.

Ostrea Marshii, Moore, Quart. Journ. Geol. Soc., 1870, XXVI., p. 232.

Alectryonia Marshii, Fischer, Man. Conch. et Pal. Conch., 1886, fas. X., p. 926, f. 690.

Ostrea Marshii, Muller in Bernhardt's Deutsch–Ost–Afrika, 1900, VII., p. 16, f. 1, 1*a*.

Obs.—There are several specimens, and all may pass as varieties of this well known and widely spread shell, " very variable in form," as James Sowerby said, and shown in Goldfuss' beautiful figures. Both the ovately oblong and fan-shaped varieties are present, and the zig-zag frontal edges are also strongly in evidence. Our specimens accord best with Goldfuss' figures *a*, *b*, *f*, and perhaps *k*. The elevated adductor is also very apparent in one. The area, as in foreign examples, is triangular and shell-like and vertically divided by a central wide chandrophore.

Locs.—Tibraddon and Sandspring Stations, Greenough River.

GENUS CTENOSTREON, *Eichwald*, 1868.
(Lethæa Rossica, 1868, II., p. 455.)

CTENOSTREON PECTINIFORMIS, *Schl., sp.*

Ostracites pectiniformis, Schlotheim, Petrefactenkunde, 1820, I., p. 231.

Ctenostreon pectiniformis, Eth., fil., Rec. Austr. Mus., 1901, IV., No. 1, p. 14, pl. 3 (for synonomy).

Ctenostreon pectiniformis, Chapman, Proc. R. Soc. Vict., 1904, XIV., (n.s.), pt. 2, p. 329, pl. 30. f. 1.

Obs.—Five examples in a poor state of preservation add little to our previous knowledge of Australian form of this species. One has the fistulous spines produced into regular elongate tubes, as shown in one of Lycett's figures.*

Locs.—Tibraddon and Sandspring Stations, Greenough River ; Fossil Hill, two miles East of Moonyoonooka Railway Station.

* Lycett—Suppl. Mon. Moll. Gt. Oolite, 1863, pl. 29, f. 1.

Genus Pecten, *O. F. Müller*, 1776.
(Zool. Donicæ Prod., p. XXXI.)

Pecten (?) cinctus, *J. Sowerby.*
(Plate IX., Fig. 1).

Pecten cinctus, J. Sowerby, Min. Conchol., IV., p. 96, pl. 371.
Pecten cinctus, Moore, Quart. Journ. Geol. Soc., 1870, XXVI., pp. 230, 231, and 232.
Pecten cinctus, Chapman, Proc. R. Soc. Vict., 1904, XVI. (n.s.), pt. 2. p. 328.

Obs.—The name *P. cinctus*, J. Sby. appeared in Moore's list of West Australian Oolitic fossils, but no complete description of either the British shell, or its supposed Australian analogue has, so far as I am aware, appeared. The original figure displays a shell defective in the region of the auricles and cardinal margin, whilst all the West Australian specimens within my knowledge are in a poor or incomplete state of preservation. In all I have nine specimens before me, seven forming a portion of the present collection and two in the Australian Museum; the largest of these measures seventeen centimeters by sixteen and a half.

I do not by any means feel satisfied our Australian shells are Sowerby's species. Sowerby said the valves of the British shell were of nearly equal convexity, but in the present instance the valves are very far from being nearly equally convex; indeed five are actually plano-convex.

The shell is sub-orbicular, more or less plano-convex, one valve moderately convex, the other flat, or nearly so; the test is thick, but as a rule much exfoliated. In the convex valve, one of the auricles (? anterior) is flat and wing-like, undivided from the body of the shell, and possibly slightly falcate along the outer margin. On the flat valve one auricle (? anterior) is triangular with a strongly falcate, or even segmoidal outer margin. The other ear of the same valve, of which a portion is still visible on one specimen, is, judging from the direction of the ornamenting laminæ, rectangular; one of the flat valves is ornamented with fine concentric lines. It may be pointed out that Sowerby's figure corresponds to the flat valve of our shells.

Locs.—Tibraddon Station; a quarter of a mile North-West, and half a mile North of Woolanooka; Sandspring Station, Greenough River; Snake River, Greenough River District.

PECTEN (?), *sp.*
(Plate VIII., Figs. 5 and 6.)

Obs.—I previously refer to *Pecten* two small slightly oblique valves, almost round in outline, very moderately convex and with small flat ill-defined triangular auricles. A very large number of strong costæ decorate the surfaces, either all of one size or alter-

nately larger and smaller, the latter interpolated, the former sometimes bifurcate. The umbo was acute and overhung the cardinal margin.

I believe this to be one of those unsatisfactory forms oscillating between *Pecten* and *Radula* and in all probability in want of a particular generic designation.

Loc.—Sandspring Station, Greenough River.

GENUS RADULA, *Klein*, 1753.

(Tent. Meth. Ostrac., p. 135).

RADULA DUPLICATA, *J. de C. Sowerby.*

(Plate VIII., Figs. 7 and 8).

Plagiostoma duplicata, J. de C. Sby., Min. Conchol., 1827, V., p. 114, pl. 559, f. 3.

Lima duplicata, Morris and Lycett, Mon. Moll. Gt. Oolite, 1853, pt. II., p. 26, pl. 3, f. 6 and 6*a*.

Obs.—Of rather common occurrence throughout the hand specimens of matrix are portions of a small *Radula*. The auricles always either hidden or defective, and all that can be said of the specimens is that the size is small, the outline oblique, and the surface covered with many radiating, direct, strong, angular costæ; between these are very much finer ribs, occupying the centres of the valleys or inter-costal spaces, and not reaching to the umbos.

In their present condition it is impossible to distinguish these fossils from the corresponding portions of *R. duplicata*.

Locs.—Sandspring Station, and a quarter of a mile South of Tibraddon Station, Greenough River.

GENUS MODIOLA, *Lamarck*, 1799.

(Min. Soc. Hist. Nat. Paris, 1799, p. 87).

MODIOLA MAITLANDI, *sp. nov.*

(Plate V., Fig. 1 and 2).

Sp. Chars.—Shell large, bold, gibbous, oblique, strongly modioliform, and transversely elongate. Cardinal margins straight, about three-quarters the length of the shell; valves convex along the obtuse diagonal ridges, which are at first nearly parallel to the cardinal margins, and then curve outwards and downwards, the valves steep on the fore side, flat on the hind surface. Anterior ends very small, almost undeveloped, the margin bluntly rounded. Ventral margins long, concave in the centre, convex at both ends. Sculpture of fine concentric lines and broad latilaminæ of growth.

Obs.—This fine shell, of which the interior is unknown, appears to be an addition to the West Australian list. For an Oolitic *Modiola* its size appears to be unusual, and quite vies with that of

M. alatus, Krumbeck, * of the Glandarienkalk of Syria ; it differs from this, however, in the possession of pronounced diagonal ridges and insinuated ventral margins.

M. Maitlandi is not unlike some *Myoconchæ*, particularly Cretaceous species. Even amongst *Modiolæ*, the size is more akin to that of the recent species *Modiola vagina*, Lamk, than it is to most fossil forms. It is named in honour of Mr. A. Gibb Maitland, Government Geologist.

Locs.—Tibraddon and Sandspring Stations, Greenough River.

Genus Cucullæa, *Lamarck*, 1801.

(Système, p. 116).

Cucullæa semistriata, *Moore*.

(Plate VI., Figs. 1 and 2 ; Pl. VIII., fig. 3).

Cucullæa semistriata, Moore, Quart. Journ. Geol. Soc., 1870. XXVI., 250, pl. 14, f. 3.

Cucullæa semistriata, Eth. fil., Ann. Rept. Dept. Mines, N. S. Wales for 1889 (1890), p. 239.

Sp. Chars.—Shell obliquely oblong, quadrate, robust, inflated. Cardinal margins considerably less than the width of the shell ; umbonal regions high, prominent ; umbos depressed, flattened above the apices curving over the area ; the latter wide, with sharp margins, and deeply excavated, the ligamentary grooves widely V-shaped, about fourteen on each moiety of the area. Anterior ends obtuse, the margins very slightly rounded or almost truncate ; anterior slopes slightly flattened but steep. Posterior ends obliquely produced, obtusely pointed ; margins above oblique, below obtusely rounded ; posterior slopes forming scalene triangles, long, slightly concave ; diagonal ridges prominent above. Articules strong ; medium denticles numerous and oblique ; lateral teeth three on each side, large and strong, the upper one practically horizontal, the median slightly oblique, the lower decidedly oblique. Sculpture of deep latilaminar grooves with between them finer concentric lines, crossed on the anterior slopes by fine radii producing a cancillated surface.

Obs.—Moore speaks of the "hinge-area bounded by a lanceolate straight space," which does not appear on the specimens before me. This species very closely resembles Goldfuss' illustration† of *C. oblonga*, J. Sby. So far as I have been able to isolate the articulus, the shell appears to be a true *Cucullæa*, at the same time the muscular scars have not been seen. *C. semistriata* is represented by the greatest number of individuals, and it may be distinguished generally by its oblong-quadrate robust form.

* Krumbeck—Beitrage Pal. Geol. Osterr.—Ung. Orients, 1905, XVIII., left 1 and 2, pl. 11, f. 4 and 5.

† Goldfuss—Petrefacta Germaniæ, Thiel 2, pl. 123, f. 2.

Locs.—Tibraddon and Sandspring Stations and half a mile North of Woolanooka, Greenough River ; Fossil Hill, two miles East of Moonyoonooka Railway Station, Greenough River District.

CUCULLÆA TIBRADDONENSIS, *sp. nov.*

(Plate V., Fig. 3 and 4).

(?) *Cucullæa, sp.* Moore, Quart. Jour., Geol. Soc., 1870, XXVI., p. 250.

Sp. Chars.—Transverse obliquely oblong, produced posteriorly only moderately inflated in the umbonal region. Cardinal margins about two-thirds the length of the shell ; umbos depressed, flattened above. Area narrow, deep ; ligamentary grooves five on each area half. Anterior ends rather obtuse, the margins almost vertical above, rounded below, the antero-cardinal junctions forming a right angle ; anterior slopes obtuse. Posterior ends long, produced, narrow, wedge-shaped, the margins all rounded, and without postero-cardinal angles ; diagonal ridges sharp umbonally becoming obtuse in their downward course and dying out ; posterior slopes slightly concave. Sculpture of latilaminæ, which are strong and corrugated on the posterior extremities, with intermediate finer concentric lines, and umbonal radii.

Obs.—Moore recorded four species of *Cucullæa* from West Australia, viz., *C. oblonga*, J. Sby., *C. inflata*, Moore, *C. semistriata*, Moore, and a fourth, to which no name was given, this last "distinguished by its being much narrower or transversely elongated." There is a strong probability of this being the shell in question. It may be at once distinguished from the others by its wedge-like produced posterior end.

Locs.—Tibraddon and Sandspring Stations, Greenough River.

CUCULLÆA, *sp.*

(Plate VII., Fig. 1 ; Pl. VIII., Figs. 1 and 2).

Obs.—The collection contains four single valves that may be Moore's first species of West Australian *Cucullæa* (*C. inflata*), although neither of them appear to be sufficiently inflated to answer to his figures. The shells before me possess an outline quite dissimilar to those referred to *C. semistriata*. It is quadrate, somewhat obliquely so, longer than broad. The cardinal margins, as Moore says of his *C. inflata*, are shorter than the width of the shell, and the umbos median and much elevated. The largest specimen is by no means perfect, but the anterior and posterior ends appear to be truncate, and there is certainly a strong posterior diagonal ridge, again as described by Moore, and a wide posterior slope. The area is wide and very high, with many ligamental furrows (more than fifteen). The entire valve is sculptured with fine concentric lines on wide latilaminæ, and anterior radii.

Moore recorded*, but neither described nor figured, the European *C. oblonga*, J. Sby.† as a West Australian species. He said "*C. oblonga* is the most frequent [species] of this genus." Sowerby's figure is drawn from a point of view very difficult for determinative purposes, but notwithstanding this, I have not seen a *Cucullæa* from West Australia I could refer to it, although the present form approaches nearest.

Loc.—Fossil Hill, two miles East of Moonyoonooka; Sandspring Station, Greenough River.

GENUS TRIGONIA, *Bruguière*, 1789.
(Encycl. Méthod. I., pl. 14).
TRIGONIA MOOREI, *Lycett.* ‡
(Plate IV).

Trigonia Moorei, Lycett. Brit. Fos. Trigoniæ, No. 4, 1878, p. 151, fig.

Trigonia Moorei, Moore, Quart. Jour. Geol. Soc., 1870, XXVI., p. 254, pl. 14, f. 9 and 10.

Trigonia Moorei, Eth. fil., Rec. Austr. Mus., 1904, No. 4, pl. 27, f. 3 and 4.

Sp. Chars.—Shell irregularly quadrate, posteriorly oblique: valves generally compressed, in advanced age becoming inflated: anterior cardinal margins short, steep; posterior cardinal margins moderately long; umbonal regions high; umbos much more anterior than posterior, fine, very slightly opisthogyrate; escutcheon elongately cordate, almost reaching to the posterior cardinal angles, bounded by fairly well pronounced carinæ; ligamentary aperture heart-shaped, short. Anterior ends small comparatively, entirely confined between the upper parts of the cinctures and the anterior margins which are rounded; posterior ends much compressed, the margins short and oblique; cinctures on leaving the umbos at first nearly vertical, then sweping down so as to just miss the postero-ventral angles, broad and shallow; diagonal ridges prominent; posterior slopes flattened, each traversed by a median radial groove. Ventral margins well rounded on the anterior side, and nearly straight medianally to the postero-ventral angles. Sculpture anterior to the cinctures of 20-23 sharp, outstanding, concentric lyræ, separated by wide, flat valleys, the former almost vertical along the anterior margins; on arriving at the cinctures the lyræ rise into flat transverse nodes, but pass over the former as faint flat laminæ, terminating at the diagonal ridges as prominent transverse echinating nodes; posterior slopes bear fine curved radii and transverse ridges giving rise to a scabrous surface, the points of intersection nodose; on the escutcheon this scabrous sculpture occurs at its very apex immediately under the umbos, the remainder

* Moore—Quart. Journ. Geol. Soc., 1870, XXVI., pp. 231, 250.
† Sowerby—Min. Conchol., 1818, III., p. 7, pl. 206, f. 1 and 2.
‡ Non *T. Moorei*, Garich.

of the surface bearing lines. Articules much arched, strong ; hinge plates thick ; nymphæ small, erect ; triangular cardinal callosity of the left valve well developed and projecting horizontally above, but distinctly hollowed below ; posterior tooth of the right valve long, fitting into a correspondingly long and deep socket of the left valve ; posterior tooth of the left valve also large and projecting.

Obs.—This, to us well-known, shell has not been described before in detail. It is one of the most characteristic West Australian Mesozoic fossils and occurs at certain localities in great profusion. The original notes published by Mr. Moore were furnished by Dr. J. Lycett, who compared *T. Moorei* with *T. costata*, J. Sby., of the European Lower Oolite and found it to differ as follows :—(1) generally more compressed ; (2) escutcheon narrower and longer (3) posterior slopes (Lycett's area) larger, more convex, more expanded, and bipartite, the median carinæ replaced by grooves ; (4) inner carinæ (bounding the escutcheon) slightly nodular and inconspicuous ; (5) anteally the lyræ approach the valve margins almost perpendicularly ; (6) no distinct anterior truncation ; (7) diagonal ridge of the right valve stronger than that of the left. Of these characters the last does not appear to hold good when a number of specimens are examined.

Mr. F. L. Kitchin considers *T. Moorei* to be of "essentially similar aspect" to his *T. dhoscensis** of the Cutch Jurassic fauna, but on a close examination the two shells need not for a moment be mistaken for one another.

There is a much higher degree of gibbosity, or inflation, in the united valves of old shells, than in those of young and median growth. In old individuals also the scabrous surface of the posterior slopes is much accentuated. Other than these points the species appear to maintain its character free of variation. The largest example to come under my notice measured two and a half inches along the cinctures from umbos to ventral margins. In absolutely unworn specimens, the interlyrate concentric striæ on crossing the cinctures rise into delicate frills.

Locs.—Tibraddon and Sandspring Stations, Greenough River ; Fossil Hill, two miles East of Moonyoonooka Railway Station ; quarter mile North-West and half mile North of Woolanooka, Greenough River and Snake Farm, Greenough River.

GENUS ASTARTE, *J. Sowerby*, 1816.

(Min. Conchol., II., p. 85).

ASTARTE CLIFTONI, *Moore*.

(Plate V., Figs. 5–8 ; Pl. VI., Fig. 3).

Astarte Cliftoni, Moore, Quart. Journ. Geol. Soc., 1870, XXVI., p. 249, pl. 13, f. 10.

Sp. Chars.—Shell ovately-trigonal, inequilateral in the extreme, compressed ; cardinal margins highly arched, strongly re-

* Kitchin—Jurassic Fauna of Cutch (Pal. Ind.). III., pt. 2, No. 1, 1903, p. 29, pl. 3, f. 1 and 2.

versed V-shaped, short on the anterior sides, and very long posteriorly. Umbos quite anterior, fine, sharp, and depressed ; lunule large, deep, ovate cordiform ; escutcheon very long, deep and narrow ; ligamentary aperture less than half the length of the escutcheon, ligament stout. Anterior ends merely fractional from the advanced position of the umbos, their brief margin quite rounded ; anterior diagonal ridges short, curved very sharp, bounding the lunule. Posterior ends consisting of what is tantamount to the entire valves, flattened, the margins rounded, forming by their junctions with the oblique cardinal margins approximate angles of 15° ; posterior slopes quite inconspicuous. Sculpture of very numerous, sharp, close, regular, concentric lyræ.

Obs.—The ovately-trigonal outline, long obliquely arched cardinal posterior margins, and compressed valves, render this an easily recognised shell. It is only to be distinguished from *A. subtrigona*, Münster,* of the Wurtemberg Inferior Oolite, by possessing a rather more oblique outline and more compressed valves. I have seen the articulus of the left valve, and it is characteristically astartiform ; the central socket for the reception of the right central cardinal is remarkably large.

Loc.—Tibraddon Station, Greenough River.

CLASS GASTEROPODA.

Genus Pleurotomaria, *Defrance*†, 1824.

(Tableau, p. 114).

Pleurotomaria Greenoughensis, *sp. nov.*

(Plate VIII., Figs. 9 and 10).

Sp. Chars.—Shell conical, gradate ; whorls six, step-like, lower portion the larger moiety and slightly oblique, the upper half nearly horizontal ; band probably represented by a slight groove around the middle of each whorl. Sculpture spiral.

Obs.—A very unsatisfactory specimen, but as univalves appear to be so scarce in collection of West Australian Mesozoic fossils, it was thought advisable to notice it. The base is incomplete, but the mouth was probably transversely oval and oblique. The finer details of sculpture also are not preserved.

Loc.—Sandspring Station, Greenough River.

CLASS CEPHALOPODA.

Genus Dorsetensia, *S. S. Buckman*, 1892.

(Mon. Inf. Oolite Ammonites, pt. VI., p. 302).

Dorsetensia Clarkei, *Crick*.

(Plate VI., Fig. 4 ; Plate IX., Fig. 7).

Ammonites radians, Moore (non Schlotheim), Quart. Journ. Geol. Soc., 1870, XXVI., pp. 230, 231, 232 ; pl. 15, f. 2.

Ammonites (Dorsetensia) Clarkei, Crick, Geol. Mag., 1894, I., (4), p. 388, pl. 12, f. 2, *a–c*.

Obs.—Seven examples of this species are before me in varying states of preservation, the largest with a diameter of three and a

* Munster—In Goldfuss, Petrefacta Germaniæ, Ed. 2, 1862, II., p. 183, pl. 134, f. 17, *a* and *b*.

† Restricted, Fischer.

quarter inches. Two of the specimens exhibit five and a half whorls and still incomplete. In casts the costæ disappear on the flanks at about the sixth whorl.

Locs.—Tibraddon Station and Snake Farm, Greenough River; Fossil Hill, two miles East of Moonyoonooka Railway Station.

GENUS PERISPHINCTES, *Waagen*, 1869.

(Benecke's Geogn-pal. Beiträge, 1869, II., p. 248).*

PERISPHINCTES CHAMPIONENSIS, *Crick* ?

Ammonites (*Perisphinctes*) *championensis*, Crick, Geol., Mag., 1894, I., (4), p. 436, pl. 13, f. 2 *a* and *c*.

Ammonites (*Perisphinctes*) *championensis*, Chapman, Proc. R. Soc. Vict., 1904, XVI. (n.s.), p. 331, pl. 30, f. 2.

Obs.—Two imperfect specimens are referred to this species one with a diameter of five and a half inches. Both exhibit the superumbilical nodes and fasciculate costæ of this and *P. robiginosus*, Crick, † indeed, it is very difficult to distinguish the one from the other.

Loc.—Tibraddon Station, Greenough River.

GENUS SPHÆROCERAS, *Bayle*.

SPHAEROCERAS SEMIORNATUS, *Crick* ?

(Plate IX., Fig. 8).

Ammonites Brocchi, Moore (non J. Sby.), Quart. Journ. Geol. Soc., 1870, XXVI., pp. 231, 232, pl. 15, f. 4.

Ammonites (*Sphæroceras*) *semiornatus*, Crick. Geol. Mag., 1894, I. (4), p. 434, pl. 13, f. 1, *a* and *b*.

Obs.—A single impression or mould in limonite may represent this species judging by the remains of the sculpture; the superumbilical or dorsal tubercle-ribs passing into more numerous median or ventral costæ are quite apparent.

Loc.—Tibraddon Station, Greenough River.

GENUS NAUTILUS, *Breynius*, 1732.

(Dissert. de Polythal).

NAUTILUS PERORNATUS, *Crick*.

Nautilus semistriatus, Moore (non D'Orb.). Quart. Journ. Geol. Soc., 1870, XXVI., pp. 230, 231, 232.

Nautilus perornatus, Crick, Geol. Mag. 1894, I. (4), p. 386, pl. 12, f. 1 *a* and *c*.

Obs.—In the present collection are three examples imperfect and poorly preserved, but still showing that the shell attained a

* *Fide* Neumayr.
† Crick—Geol. Mag., 1894, I. (4), p. 438, pl. 13, f. 3, *a*, and *b*.

large size. The largest consists of a portion of the venter and one flank, the former bearing revolving costæ, and the latter coarse lines of growth. This specimen measures round the venter sixteen inches, and across the same, four and a half inches. The second example is similar but smaller, whilst the third is part of a flank and half a venter again exhibiting the revolving costæ, but in this instance on both, with septal sutures and cameræ. The third example is a much smaller specimen, about double the size of Mr. Crick's figure.

Loc.—Tibraddon Station, Greenough River and Fossil Hill, two miles East of Moonyoonooka Railway Station.

EXPLANATION OF PLATE IV.

TRIGONIA MOOREI, *Lycett.*

Fig. 1.—A full grown specimen of a left valve showing the lyræ passing across the cincture as frills.

„ 2.—A similar valve the lyræ terminating in tubercles before passing over the cincture; the posterior slope with semi-concentric lyræ and median shallow radial groove.

„ 3.—Slightly smaller example with the eschinated sculpture of the posterior slope and well developed nodes along both sides of the cincture.

„ 4.—A similar specimen to Fig. 3.

„ 5.—Articulus of a left valve showing the projecting cardinal socket-like callosity and teeth.

„ 6.—Internal cast of the right valve.

„ 7.—Internal cast of the united valves seen from above.

„ 8.—The same seen from the anterior.

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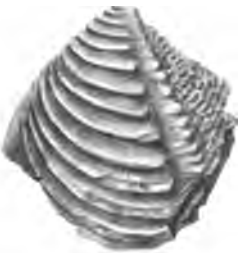

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EXPLANATION OF PLATE V.

MODIOLA MAITLANDI, *Eth. fil.*

Fig. 1.—Left valve of a well preserved example.

„ 2.—The united valves seen from above.

CUCULLÆA TIBRADDONENSIS, *Eth. fil.*

„ 3.—Left valve slightly imperfect.

„ 4.—The united valves seen from above, exhibiting the area.

ASTARTE CLIFTONI, *Moore.*

„ 5.—Right valve showing the general outline and close regular concentric lyræ.

„ 6.—United valves seen from above with the escutcheon and ligament.

„ 7.—Anterior end of the united valves with the lunule.

„ 8.—Articulus of the left valve.

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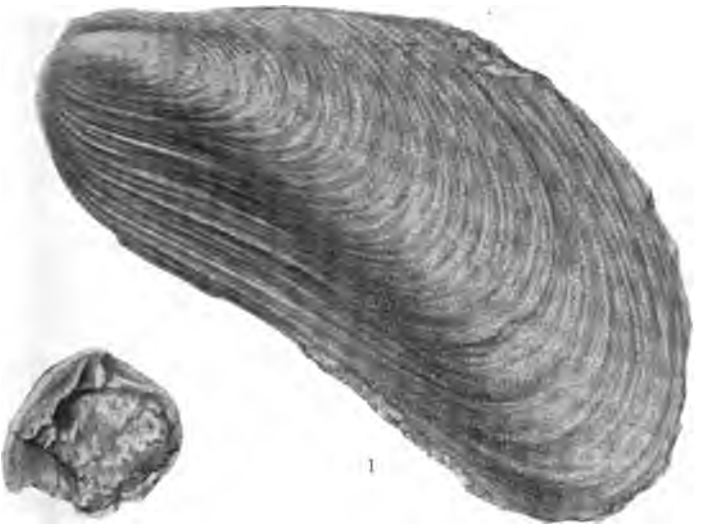

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Frank R. Leggatt, Del.

EXPLANATION OF PLATE VI.

CUCULLÆA SEMISTRIATA, *Moore*.

Fig. 1.—Left valves nearly complete.

„ 2.—United valves seen from above, exhibiting the area.

ASTARTE CLIFTONI, *Moore*.

„ 3.—Right valve of an individual with fine lyræ.

DORSETENSIA CLARKEI, *Crick*.

„ 4.—An imperfect shell exhibiting costæ on the inner whorls, also sutures and keel of the venter.

ALECTRYONIA MARSHI, *J. Sowerby*.

„ 5.—Interior of portion of a fan-shaped (?) valve with the elevated adductor scar.

„ 6.—Exterior with subradiating costæ and partial view of the zig-zag frontal edge.

„ 7.—Interior of a subtriangular valve with the elevated adductor scar, and large triangular area and its wide chondrophore.

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Frank R. Leggatt, Del.

EXPLANATION OF PLATE VII.

CUCULLÆA, *sp.*

Fig. 1.—Left valve nearly complete with latelaminæ bearing subordinate concentric lines, crossed at the anterior end by fine radii. (This may be *C. inflata*, Moore.)

OSTREA THOLIFORMIS, *Eth. fil.*

.. 2.—Exterior of flat valve.

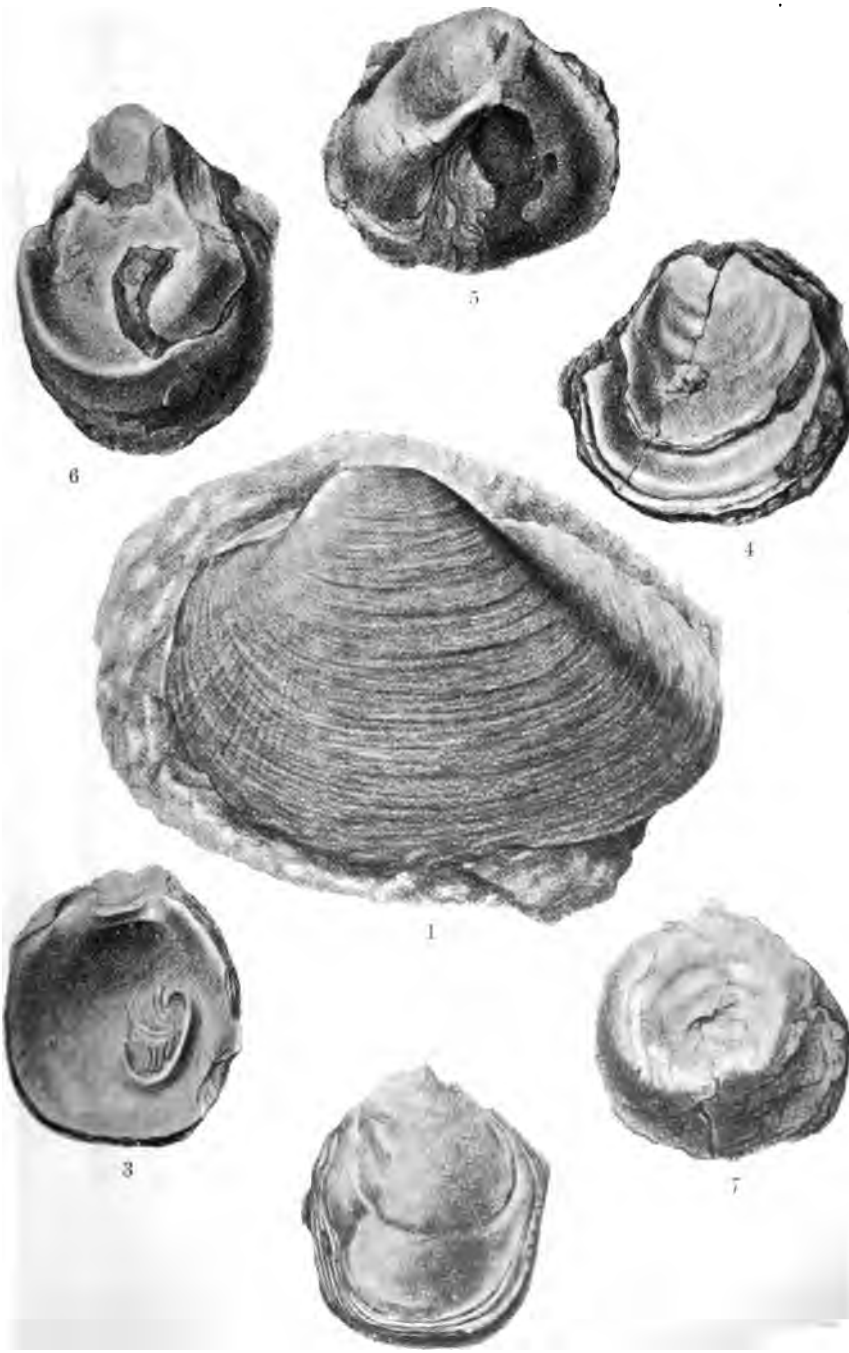
.. 3.—Interior of the same valve with the elevated adductor scar rim and *Serpulæ*.

.. 4.—Another example of a flat valve.

.. 5.—The attached dome-shaped valve more or less exfoliated.

.. 6.—A much exfoliated attached valve.

.. 7.—Another similar valve, but less dome-shaped than Fig. 5, and with a larger area of attachment.



Frank R. Leavitt, Del.

EXPLANATION OF PLATE VIII.

CUCULLÆA, *sp.*

Fig. 1.—Imperfect Right valve, possibly referable to *C. inflata*, Moore.

.. 2.—Umbonal elevation and partial area of the same specimen.

CUCULLÆA SEMISTRIATA, *Moore.*

.. 3.—Umbo, area, and teeth of the articulus.

ALECTRYONIA MARSHI, *J. Sby.*

.. 4.—An imperfect specimen exhibiting the strong subradiating costæ, and undulating or zig-zag front.

PECTEN (?), *sp.*

.. 5.—A small valve provisionally referred to *Pecten* with strong costæ.

.. 6.—Another valve, probably the opposite to that represented in Fig. 5.

RADULA DUPLICATA, *J. de C. Sby.*

.. 7.—Portion of a valve, less the auricles.

.. 8.—The costæ, primary and secondary, much enlarged.

PLEUROTOMARIA GREENOUGHENSIS, *Eth. fil.*

.. 9.—The shell seen in elevation.

.. 10.—The base.

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Frank R. Leggatt, Del.

EXPLANATION OF PLATE IX.

PECTEN (?) CINCTUS, *J. Sby.*

Fig. 1.—Flat valve much exfoliated, with remains of the auricles.

OSTREA, *sp.*

„ 2.—Interior of an upper or flat valve exhibiting area above. test laminæ at the sides, and the adductor scar.

RHYNCHONELLA VARIABILIS, *Schlotheim.*

„ 3.—Umbo of the pedical valve, and the brachial valve with the fold occupied by three costæ.

„ 4.—Lateral view of the specimen represented in Fig. 3—× 3.

„ 5.—Pedicle valve of the specimen represented in Figs. 3 and 4 ; the sinus occupied by two costæ—× 3.

„ 6.—A second specimen, the fold of the brachial valve bearing two costæ —× 3.

DORSETENSIA CLARKEI, *Crick.*

„ 7.—A large example exhibiting the costæ and keel of the venter.

SPHÆROCERAS SEMIORNATUS, *Crick* (?).

„ 8.—Cast from a natural mould in limonite displaying a very imperfect specimen.

IV.—Sthenurus Occidentalis (Glauert).

BY

LUDWIG GLAUERT, F.G.S.

Field Geologist.

Introduction.

In the course of a construction of a pathway in the Mammoth Cave, Margaret River, 1904, the workmen found it necessary to break into a large boss of Stalagmitic material. As soon as the external layer had been removed, bones, mostly in a fragmentary condition, were encountered. Many of these were laid on one side, but, owing to the true significance of the discovery not being evident to those engaged upon the work, many valuable portions were doubtlessly destroyed or lost, while those to hand have suffered considerably from the rough usage to which they have been subjected.

Mr. E. A. LeSouef, the Director of the Zoological Gardens, collected numerous specimens, which he had conveyed to Perth, where, in due course he handed over the majority to the Secretary of the Caves Board of Western Australia, the authority controlling the cave where the bones were found. In November, 1908, Mr. LeSouef, made a further delivery of fossil remains, obtained with those previously handed over, including a lower jaw which he had recognised as belonging to *Sthenurus*, an extinct genus of the Macropodidæ not previously recorded from this State.

The Caves Board, aware of the great importance of the find, submitted the specimens for examination and description. The report, dated January 26th, 1909, was submitted to the Board at the meeting held on Friday, January 29th.

ORDER MARSUPIALIA.

Sub-order Diprotodontia.

Family Macropodidæ. Sub Family Macropodinæ.

Genus Sthenurus, *Owen* 1873.

Sthenurus (1) Owen Proc. Roy. Soc. London XXI., No. 141, p. 128—1873.

(1.) Synonomy *Fide* Trouessart's "Catalogus Mammalium" Tom. II., 1900.

Owen Phil. Trans. Roy. Soc. London, CLXIV., pt. I., p. 265—1874.

Lydekker Cat. Foss. Mam. Brit. Mus. (N.H.) pt. V., p. 232—1887.

Lydekker Handb. Marsup. p. 253—1894.

DeVis. Proc. Lin. Soc. N.S.W., 2nd Series, Vol. X., p. 88—1895.

Protemnodon (partim) Owen Proc. Roy. Soc. London, XXI., No. 141, p. 128—1873.

Owen Phil. Trans. Roy. Soc. London, CLXIV. pt. I., p. 274—1874.

Procoptodon Owen Proc. Roy. Soc. London, XXI., No. 145, p. 387—1873.

Owen, Phil. Trans. Roy. Soc. London, CLXIV., pt. II., p. 786—1874.

Pachysiagon (n.n.) Owen Proc. Roy. Soc. London, XXI., No. 145, p. 386—1873.

Owen Phil. Trans. Roy. Soc. London, CLXIV., pt. II., p. 784—1874.

Macropus (partim) (1) Owen Mitchell's 3 Exped. East Austr., Vol. II., p. 359—1838.

Owen Descr. Cat. Mam. Aves. Roy. Coll. Sur. London, p. 325—1845.

Macropus (*Sthenurus*) *atlas* (type) Wellington Valley, N.S.W.

STHENURUS OCCIDENTALIS, GLAUERT.

Sthenurus sp. nov. Glauert Proc. Geol. Soc. London, No. 881, p. 120—1909.

Quart. Journal Geol. Soc. London, Vol. LXV., p. 462—1909.

Sthenurus occidentalis sp. nov. Records W.A. Museum, Vol. I., pt. 1, p. 31, etc., 1910.

Prof. Owen's description of *Sthenurus atlas*, which is the type of the genus, is published in the Philosophical Transactions of the Royal Society of London, CLXIV, Part I., 1874, pp. 265–274, with figures (2) and is rather too lengthy to quote here, particularly as much abbreviated accounts of the generic characters are given by later authors.

Mr. R. Lydekker, the author of the Catalogue of the Fossils Mammalia in the British Museum (N.H.), suggests radical alter-

(1.) *See* also Owen "The Extinct Mammals of Australia" 1877, a work which contains the results of Prof. Owens' researches on the extinct Marsupials of Australia united in book form.

(2.) This description is repeated in Owen's "Extinct Mammals of Australia," 1877, pp. 416—424, etc.

ations in part V. of that work. He restricts the Genus of *Sthenurus* to one species only *S. atlas*, and places all the other species under *Macropus*. Further he states (1) "It will be shown in the sequel that all the upper jaws described by Owen under the name of *Sthenurus* and the lower ones as *Protemnodon*, indicate large Wallabies belonging to the present genus: (*Macropus*), although the genus *Sthenurus* as defined below, is a valid one."

On page 231 of the same volume we find the description of *Sthenurus*. "The fourth upper premolar develops a complete inner, and the lower one a corresponding outer lobe, so that the worn crown of these teeth present oval, flat surfaces, and have no secant edge. The true molars have no vertical enamel folds, and are short and wide: the longitudinal bridge connecting the ridges being very imperfect, and the anterior talon of the upper molars unconnected by such a bridge with the first ridge. The mandibular symphysis is not anchylosed, and the lower incisors are of the macropine type. The Genus connects *Macropus* with *Procoptodon*. This latter genus was described as follows (2) by Mr. Lydekker: "Genus *Procoptodon* (Owen). The mandibular symphysis is anchylosed in the adult, and the ramus of the mandible short and deep, the diastema being also short. The premolars resemble those of *Sthenurus* in structure, but the true molars are elongated and usually have their enamel thrown into a series of vertical folds. There are large palatal vacuities: and the lower incisors are subcylindrical."

There being a large stock of material in the Queensland Museum, the curator, Mr. C. W. DeVis, examined the specimens in that collection with a view of adopting the new classification. He found, however, that he could not separate *Sthenurus* and *Procoptodon* on account of the numerous intermediate-forms, and therefore wrote (3). "An amalgamation of *Procoptodon* with *Sthenurus* is demanded by their verisimilitude of tooth sculpture, and by the occurence of forms of transition between the two. Owen's reference of the maxilla of *Protemnodon anak* to *S. atlas* has been accounted for by Mr. Lydekker."

The enlarged Genus *Sthenurus* is defined by Mr. deVis in those terms:—

> "Lower permanent premolar with an obliquely disrupted lobe forming the posterior moiety of the outer side, the cleft occupied by sinuous and papillary folds. Upper permanent premolar with a broad ledge on the inner side its cavity traversed by erect folds. Molars short, with ascending, tapering, spreading folds incumbent on their surfaces; posterior, basal, margins tumid, but rarely forming distinct talons, mandibular symphysis generally anchylosed; lower incisors generally small, laterally compressed and much less incumbent than in other Macropods. A vascular foramen on the outer side of the mandible beneath one of the posterior molars. Posterior orifice of dental canal generally above the level of the teeth. Palate with large vacuities."

(1.) *op.* cit., p. 207.
(2.) *op.* cit., p. 233.
(3.) Proc. Lin. Soc. N.S.W., 2nd series, Vol. X., p. 88—1895.

As the specimen under consideration possesses characteristics associated by Mr. R. Lydekker with *Procoptodon* and *Sthenurus* as distinctive features and also disagrees with both of them in several important points (×) it has been considered advisable to adopt the name of *Sthenurus* in the wider sense suggested by Mr. C. W. deVis.

Description.

The specimen consists of the major portion of the left mandibular ramus, embracing the incisor, the diastema, all the cheek teeth and the lower part of the coronoid united in the position of nature to the right ramus which is perfect up to and including the third cheek tooth (m2) (1). The state of the teeth show that the last molar (m4) has been in use for some time before the death of the animal, the individual would therefore be classed as *aged* by Mr. Oldfield Thomas (2) and as *adult* by Mr. C. W. deVis (3). All the milk teeth have been shed, and of the permanent dentition every member shows signs of wear.

It is possible to take the following measurements, chiefly on the left side.

Incisor (*i*) length from base of enamel to the extremity of the worn crown 22 m/m: length of cutting edge of crown 13 (1) thickness of crown 6·5; vertical diameter at base of enamel 11; transverse diameter 7.

Diastema. Length, from posterior base of enamel of incisor to anterior edge of socket of premolar (p4) 22·5.

Cheek teeth.—Length of entire series, *in situ*, from anterior edge of p4 to hind edge of m4 61.

Premolar (p4) antero posterior dimension 17, summit of crown 12·5, greatest width of anterior moiety 7, of posterior 9.

First Molar (m1) (5) length 10·5, width fore lobe (6) 8·5, hind lobe 8·5.

Second Molar (m2) length 11·5, width fore lobe 8·5, hind lobe 9·5.

Third Molar (m3) length 12·5. width, fore lobe 10, hind lobe 10.

Fourth Molar (m4) length, 11·5, width, fore lobe 9·5, hind lobe 9.

The Mandible.—Length of jaw from the tip of the incisor to the hind margin of the coronoid 160: greatest depth in front of

(×) This specimen has the anchylosed symphysis, the short and deep ramus, the short diastema and the vertical folds in the enamel of the molars of *Procoptodon* associated with the short and wide molars of *Sthenurus*, the longitudinal links are but faint.

(1.) At the time of the preparation of this Report, I was permitted by the Director of the W. A. Museum to examine several boxes of specimens presented to that Institution by the Caves Board, and I had the good fortune to find the remainder of the right ramus so that the specimen is practically a complete lower jaw. This description simply deals with those portions submitted by the Caves Board in December, 1908.

(2.) Catalogue of Marsupialia and Monotremata in the collection of the British Museum (NH.) p. 7, 1888.

(3.) "A Review of the Fossil Jaws of the Macropodidæ in the Queensland Museum." Proc. Linn. Soc. N.S.W., 2nd series, Vol. X., p. 79—1895.

(4.) As all the measurements are given in millimeters it is proposed to omit the m.m. in this section.

(5.) This corresponds to the d4 of Professor Owen. The m1 of this authority agrees with the m2 of later writers.

(6.) In this list of measurements, the width of the lobes of the molars is the extent of the cutting edges of the lobes.

p4—34, greatest depth at m4, 35: depth behind p4, 31. Thickness under p4—15, behind m3—18, anterior dental (vascular) (1) foramen 7½–8, below the diastemal border and slightly in advance of p4. A second, smaller foramen 15 below the base of the posterior lobe of m1.

The Teeth.

The Incisors. (*i*).

These teeth are shorter, but vertically longer, than in Macropus, they gradually taper from the base to the extremity and have an outline very similar to the corresponding teeth of *S. atlas*, as figured by Owen (2) though their working surface is relatively longer, a feature which is no doubt due to the greater age of the individual. the inner surfaces of the tooth are covered with enamel, whilst even on the former there is an inverted V-shaped sinus caused by the encroachment of the radical cement.

At the socket the teeth have an oval or elliptical section, and an ovate, almost lozenge-shaped one at the base of the enamel.

Fig. 1.

L.G., del. p4 × 2.

The left lower premolar (p4) outer aspect, twice the natural size

Fig. 2.

L.G., del. p4 × 2.

The same, seen from above, twice the natural size.

The Premolar (p4). Figs. 1 and 2.

This tooth is elongately oval in horizontal section, possessing a marked constriction at a point 7 m/m from the anterior basal edge, chiefly on the outer aspect, which almost divides the tooth into a fore and a hind lobe: the constriction passes upwards and backwards to the cleft which proceeds obliquely along the crown of this tooth so that the lobe forming the anterior portion of the outer surface of the crown occupies the whole of the inner face. At the anterior extremity of this cleft there is a notch in the crown of the tooth. The posterior part of the crown is shorter than the

(×.) This specimen has the anchylosed symphysis, the short and deep ramus, the short diastema and the vertical folds in the enamel of the molars of *Procoptodon* associated with the short and wide molars of *Sthenurus*, the longitudinal links are but faint.

(1.) Later authorities term this the mental foramen.

(2.) Phil. Trans. Royal Soc. 1874, Plate XXII., figs. 5 and 6, and Extinct Mammals of Australia, Plate LXXXII., figs. 5 and 6.

crown of the succeeding molar, it was evidently used for crushing or pounding as it has a broad working surface with complex transverse ridging between the inner and the outer edges. Of the complex folds or ridges one is of much greater size and prominence than the rest.

The outer and inner faces of the fore part of the tooth each possess three more or less distinct folds which pass upwards from the prebasal ridge : the apices of the first and second form the well-marked anterior prominence of the tooth, the third reaches up to the ridge that passes backwards from the prominence to the hind part of the crown. This ridge after having been traversed by the notch of the point of the constriction passes uninterruptedly to the intero-posterior angle, here it is broken by a distinct vertical fold, then it sweeps round to form the curved trenchant edge of the postero-external lobe and to join the fore and aft ridge at the point of constriction. A faint prebasal ridge can be traced on the fore, inner and outer aspects of the tooth but is entirely absent from the hind face, which is perfectly smooth and plain from side to side, and base to crown.

Fig. 3.

L. D., del. m2 × 2.

The second right lower molar (m2) seen from above, twice the natural size.

The Molars (m1—m4). Fig. 3.

These teeth are short and wide, the lobes are thin and almost straight, being slightly convex backwards. The crests of the lobes are slightly concave, angles sharp, forming a sharp point on the inner edge, but on the outer one resembling a somewhat thickened protuberance from which a marginal fold proceeds downwards and forwards almost closing –in the case of the one from the hind lobe –the mid-valley, the fold from the fore lobe fringing the outer edge of the fold that forms the anterior ledge, or talon, of the lobe. Similar marginal folds, but branching are to be seen on the anterior surface of the inner angle of the fore lobe, and are represented by a simple marginal fold on the anterior surface of the inner angle of the hind lobe. External incumbent fold on the fore lobe large and

prominent sweeping round to form a sharp ridge along the anterior ledge or talon of the tooth. The second fold is very short and almost rudimentary, the third slightly less prominent than the first, branching, the branches reaching to the base of the anterior ridge, three or four additional folds are more or less indistinct. In a worn tooth most of these folds are very difficult to distinguish.

Several vertical folds on the hind surface of the fore lobe, only two of which can be seen distinctly, the outer one forming the longitudinal link and the second giving rise to a subsidiary link. A third very subordinate vertical fold forms a faint line reaching to the inner angle of the hind lobe. Two or three additional markings are present, evidently corresponding to the insignificant folds on the fore surface of the hind lobe. Hind surface of the hind lobe ornamented with numerous, about nine, rudimentary vertical folds which pass down to the slight post basal swelling that can hardly be termed a ridge.

The Ramus. (Plates X., XI., XII.)

The lower jaw is strong and powerful, it differs considerably from that of *Macropus*, firstly it is much more solidly built, which, together with the shape and size of the teeth, suggests that the animal's food consisted of hard vegetable matter ; secondly, the diastema being short and straight and not long and curved, the contour of the upper border of the ramus differs to a marked extent from that of *Macropus*.

As in Owen's figure of *S.atlas* (1) we find a large foramen present on the outer side of the mandible below the diastema and slightly in front of p4, as well as a second smaller one which is placed under m1 instead of beneath one of the posterior molars. The rear portion of our specimen shows the fenestral vacuity in the form of a pouch having its opening slightly below the level of the alveolar platform, it communicates with a pouch on the inner surface of the jaw by means of a fenestral foramen. The posterior opening of the dental canal is also distinctly to be seen in the pouch.

The post-alveolar platform has a sharp inner border and a most distinct angle. The outer face of the ramus bears a platform under and round the base of p4 and a short groove commencing 15 m/m below the crown of p4 and extending as far as the hind edge of m1.

Immediately below this channel the outer surface of the ramus swells considerably so that the section is fairly convex in a vertical direction though almost straight horizontally.

On the inner face of the ramus the ramus thins rapidly below a well-marked ridge that runs obtusely along the ramus, connecting the posterior extremity of the alveolar platform with the lower end of the symphysis. The symphysis is anchylosed and large in extent ; above it there is the postsymphysial depression which

(1.) Phil. Trans. Royal Soc. London, 1874, Plate XXII., fig. 5.

is present in both rami and consists of a channel communicating with a foramen (?)

Little of the coronoid process is to be seen, still it is evident that the anterior border of the ascending process ran at right angles to the line of the molars.

The lower border of the mandibles shows a distinct upward arch rising abruptly at the posterior end of the symphysis.

Compared with *S. atlas*, as figured by Owen, the ramus is seen to be considerably deeper and thicker in proportion to its longitudinal extent, the diastema is markedly shorter, 12½ m/m—and the incisors much more inclined.

Sthenurus occidentalis.

Specific Characters.—Longitudinal links continuous, with the outermost of the incumbent folds, low, but distinct; a second link, lower and very indistinct in a worn tooth, present in the mid-valley of all the molars. Posterior basal ridge absent in m1 and but faintly in the other molars.

Mandible thick, symphysis anchylosed. Incisor inclined, posterior dental foramen below the lower of the teeth, level with the alveolar groove. Anterior edge of the coronoid process rising at right angles to the line of the teeth ; under surface of the mandible arched upwards. Diastema short. Ramus thinner than in *S. oreas* (DeVis), and deeper than in *S. atlas*. (Owen).

Note.—The subsequent examination of several additional specimens shows that " the external incumbent fold on the fore lobe which sweeps round to form the sharp ridge along the anterior talon of the tooth " is ornamented with two or three vertical folds on its outer aspect. (1.)

Differences and Resemblances.

S. goliah, Owen. *S. rapha*, Owen, and *S. pusio*, Owen.

These forms are much larger in size and have differently shaped rami and teeth. The ornamentation is also of a different pattern.

S. pales. Owen.

This form is much larger in size but resembles *S. occidentalis* in the arrangement of the incumbent folds on the anterior aspect of the fore lobes of the molars and in the sculpturing of the posterior surfaces of both the fore and hind lobes.

S. otuel. Owen.

This species is of much greater size than the specimen under review, and has teeth which are differently shaped but which bear ornamentations very similar to those found on *S. occidentalis.*

(1.) *Vide* also sequel.

S. oreas. DeVis.

Our form has the same general outline as this species and the same depth of ramus as well as an anchylosed symphysis. On the other hand, the teeth are of different dimensions, as will be seen from the table below. The ramus is also considerably thinner than that of *S. oreas*, so that there can be no hesitation in looking upon our form as distinct from this Queensland species—we must bear in mind that ours is the jaw of an " aged " or adult animal in whose skeleton no further developments are to be expected.

	S. oreas (†).	*S. occidentalis.*
Cheek series	..62·2 m/m ..	60–61 over all
m1–m4	..58	45 ,,
m1–m3	..41·5	32–33 ,,
p4	..11·9	12·5 (17) ,,
m3 (length of) ..	..14·6	12·5 ,,
m3 (width of) ..	..12·1–13·2 ..	10 ,,
Thickness of mandible	..22·5–25·8 ..	15 x 17 or 18
Anterior depth of mandible	34·2	34
Posterior depth of mandible	35·5	35

S. atlas. Owen.

This species (according to DeVis, *loc. cit.*) is distinguished from *S. oreas* by having a much more slender ramus and by the fact that the symphysis is not anchylosed. In shape too, the ramus is flat exteriorly, increasing in depth posteriorly. Lower contour lines straight or arched upwards.

Against this, our form is thick, the exterior surface slightly convex longitudinally (horizontally), much more so vertically. Lower contour line arched upwards. Symphysis anchylosed.

Owen's figure of *S. atlas* (1) shows a ramus which differs from *S. occidentalis* in one or two other points; for instance, it has a longer diastema and shows very little if any trace of the inverted ridge or projection which is so evident on the inner side of the ramus of our form of *Sthenurus*.

As regards measurements we find the following relations :—

	S. atlas (2).	*S. occidentalis.*
Cheek series	55·8–58·6	60–61 over all
m1–m3	30·1–31·6	32–33 ,,
p4	12·1 x 6·8–12·8 x 7	12·5 x 6 (17 x 7 x 9) over all
m3 (width of) ..	8·9–10·5	10 over all
Thickness of mandible	14·8–15·6	15–17 or 18
Anterior depth of mandible	26·1–28·5	34
Posterior depth of mandible	29–32·7	35

(†.) *Op. cit.*, p. 96.
(1.) Owen. Phil. Trans., 1874, pl. XXII., figs. 5, 6, 7 and 8.
(2.) De Vis., op. cit. p. 98.

There is evidently a close relationship between our form and these last two species.

Since the above description was written I was engaged by the Western Australian Museum Committee and the Caves Board of W.A. to undertake further explorations in the Mammoth Cave. Amongst 2,000 specimens, several mandibular rami of *S. occidentalis* were obtained which, upon examination, confirmed the description and measurements given in my report to the Caves Board. All the specimens obtained were presented to the Western Australian Museum by the Board in March 1909.

Note.—Amongst the specimens transferred to the Department by the Western Australian Museum authorities in 1908 were four large fragments of rock with a label "Gypsum from Cliffy Head, Dongara."

Upon these being examined by Mr. E. S. Simpson and myself at that time, traces of animals remains were observed, and the material in which the bones were embedded identified as Limestone and Stalagmite, not Gypsum. The specimens were therefore laid on one side for further examination. Subsequently I was instructed to examine the material, and as a result I have been able to extract a portion of the left lower jaw of a *Sthenurus*. The state of preservation of the fossil, the nature of the matrix, and the numerous inclusions of fragments of charred wood, twigs, and branches of trees, snail shells, together with the casts of leaves of Eucalypts, and the fact that the fossil is a *Sthenurus occidentalis*, cause me to state with every confidence that the specimens must have come from the Mammoth Cave, Margaret River, S.W.

Most likely they are a portion of the collection made by the Director of the Museum, Mr. B. H. Woodward, during his visit to the Cave in August, 1905. (1).

The specimen [**10087**] is somewhat damaged, but still it bears the socket and root of the incisor, the premolar p4 (2) and the first, together with the anterior half of the second molar m1 and m2.

MEASUREMENTS.

The following measurements are possible:—

The Teeth.—p4 length (crown 12·5 m/m)		14·5 m/m over all
Width of fore lobe cutting edge	.. .. ..	7·5
Width of hind lobe cutting edge	.. .. ..	9
m1. length of crown	..	10·5
Width of fore lobe cutting edge	.. .. ..	8·5
Width of hind lobe cutting edge	.. .. ..	9
m2, length ..	.. ..	
Width of fore lobe, cutting edge	.. .. ..	9

(1.) Records of the W.A. Museum, Vol. I., part 1, p. 10—1910.
(2.) The dental formula in use in the British Museum (N.H.) is adopted, the manner in which it differs from that proposed by Prof. Owen has already been referred to.

The Mandible—

Depth of mandible in front of p4 about	.. 36 m/m
Depth of mandible behind p4 ..	.. 31·5
Thickness under p4	.. 15

The anterior dental foramen (1), 3½m/m in diameter, is situated about 8m/m below the diastemal edge, and slightly in advance of p4. The length of the diastema, which is imperfect, would be about 22m/m.

Description.—The premolar (p4) differs somewhat from the corresponding tooth of the type of the species; the most important feature is the presence of a small cusp or tubercle on the inner half of the anterior aspect of the tooth. The suggestion of a similar process is seen on the premolars of some of the mandibles in the W.A. Museum Collection.

The foldings of the complex transverse ridging on the broad working surfaces, which occupies the posterior portion of the crown, is rather more complicated, perhaps due to the state of wear of the tooth, but more likely an individual feature, for the examination of all the premolars of *S. occidentalis* which I have been able to examine shows slight variations in the arrangement of these folds. The vertical fold in the enamel at the intero-posterior angle is so worn that all but the base of the conical pit has been removed.

The outer aspect of the tooth is very similar to that of the type, but the inner one bears traces of two or three rudimentary vertical folds, just beneath the posterior portion of the crown, which are not to be seen on the type.

The Molars.—The first molar (m1) is very much worn, the summits of the outer extremity of both fore and hind lobe are so worn that in each case the dentine is exposed. The ornamentation of the teeth is as in the type, with the addition that the vertical folds on the hind surface of the hind lobe of m1 rise from an arched post-basal ridge which, though slight, is quite distinct (†), and that though this animal was considerably older than the type at the time it met its death, the vertical folds on the outer aspect of the "external incumbent fold on the fore lobe, which sweeps round to form a sharp ridge along the anterior talon of the tooth" can be seen with the aid of a lens. These folds are not very prominent in some specimens, and seem to be soon worn away—they are exceptionally distinct on the second molar of the specimen in the departmental collection, and have been recognised on the type specimen (2) since it was described.

The Ramus is very strong, that portion which is preserved has the same thickness as the type, but the depth is somewhat greater, both before and behind p4 due. no doubt, to the greater age of the animal (3). The exposed root of the incisor enables

(†) In my examination of the type specimen I could find no trace of any post-basal ridge on *m1*.

(1.) Prof. Flower has designated this foramen the mental foramen, *see* Osteology of the Mammalia.

(2.) *See ante* p.... and Records of the W.A. Museum, Vol. I., part 1, p. 36—1910.

(3.) This increase in depth of the ramus as the animal ages is a common feature with the Macropodidæ.

one to guess the length of the diastema which, had it been perfect, would have had the same extent as in the type. The state of the fractured inner surface at the root of the incisor proves that the symphysis was anchylosed.

The discovery of this specimen is interesting, as it helps to prove that the features seen and recognised upon the type of the species as points of difference are not merely individual variations, but characteristics of a group of animals—a distinct species of *Sthenurus*. The presence of the vertical folds on the outer aspect of the external incumbent fold on the anterior lobe of every molar of this species yet examined is an important additional feature peculiar to *S. occidentalis*.

EXPLANATION OF PLATES.

Plate X.—The united rami seen from above.

Plate XI.—Exterior aspect of left ramus.

Plate XII.—Interior aspect of same.

Sthenurus occidentalis (Glauert) × ¾.

The united rami seen from above.

Sthenurus occidentalis (Glauert) × ¾.

Exterior aspect of left ramus.

Sthenurus occidentalis (Glauert) × ¾.

Interior aspect of left ramus.

V.—A List of Western Australian Fossils (systematically arranged),

BY

LUDWIG GLAUERT, F.G.S.,

Field Geologist.

General Introduction.

This list is an attempt to catalogue all the Western Australian Fossils that have been collected in the State up to the end of 1908.

Whilst every care has been taken to make it as complete as possible, it is felt to be far from perfect owing to the vagueness of some of the localities, the uncertainty of various names, and the disappearance of many of the specimens.

Although Western Australian Palæontology is still in its infancy several attempts have been made to catalogue the forms then known.

In 1870 Chas. Moore compiled a list of the Mesozoic Fossils (*vide* Q. J. G. S., Vol. XXVI., 1870, p. 232), which was the authority for Mr. Etheridge's "Catalogue of Australian Fossils" of 1878—as far as the Western Australian Fauna was concerned. Some five years later W. H. Hudleston gave a list of the Palæozoic Fossils that had been submitted to him for examination and description (*vide* Q. J. G. S., Vol. XXXIX., 1883, p. 590). The next list compiled was that published in the Annual General Report for 1890, by Mr. H. Page Woodward, at that time Government Geologist. This was the first attempt to classify all the Western Australian Fossils, and is the most comprehensive Catalogue that is known to this Department at the present time. In order to show the advances made in Western Australian Palæontology since that date, all the species then recorded are prefixed with the letter "W" in the following pages. Since 1891, untabulated lists have appeared in the following Government publications and in the presidential address, Section "C," Geology, at the Adelaide meeting of the Australasian Association for the Advancement of Science, 1907, all over the signature of Mr. A. Gibb Maitland, the present Government Geologist of this State. Although up to date, they do not claim to be complete or systematically arranged, and so do not fill the place that this present catalogue is intended to occupy.

Bulletin No. 4.—The Mineral Wealth of Western Australia, Chapter I. 1900.

Bulletin No. 26, part 7.—Recent Advances in the Knowledge of the Geology of Western Australia, 1907.

Year Book.—Western Australian Year Book (article "Salient Geological Features"), from Bulletin No. 4, 1902–4.

It was the original intention to include all the Western Australian Fossils in this present list, but more careful investigation of the specimens and their labels show that almost all the Cainozoic examples were badly preserved casts, which did not permit an exact determination. As it would be useless to include such very doubtful records, it was thought more advisable to confine the list to the Palæozoic and Mesozoic Times only, and to leave the Cainozoic and more recent examples till better preserved specimens came to hand, or circumstances permitted more time being spent upon them, so that some definite result might be obtained.

Again, the known fossil flora of Western Australia is so small and insignificant that it was considered the wiser plan to confine it to a separate article.

The plan adopted is to a great extent similar to that of Mr. Etheridge: the animal remains are in zoological order (after Zittel), and occupy the first longitudinal subdivision; in the second subdivision the localities are placed in geographical sequence from North to South; the third column is reserved for references to publications, which are indicated by letters of the alphabet, *see* page 73 (when the letters represent works containing figures or illustrations of the species they are printed in capitals); then follows the subdivision containing the names of the Museums known to contain Western Australian Fossils, here the presence of a species is recorded by means of a ×. As this list is designed chiefly for use in this State it was considered an advantage to distinguish species represented in the Geological Gallery of the Western Australian Museum by printing the names in a **heavier type.** Species exhibited in other Museums, and not in the National Collection, have their names printed in ordinary type, whilst the name of specimens that are recorded but cannot be traced to any collection are printed in *italics*.

In compiling this work the first Bulletin issued by the Department, The Bibliography of the Geology of Western Australia, by A. Gibb Maitland, 1898, was freely used, and all its references consulted wherever possible.

For articles of later date, manuscript notes made by the Government Geologist were found of great assistance. The Assistant Keeper of the Geological Department of the British Museum (Natural History), the Assistant Secretary of the Geological Society of London; the Directors of the Western Australian Museum; the Australian Museum, Sydney; the National Museum, Mel

bourne ; the Public Library, Museum, and Art Gallery, Adelaide ; the Museum of the Geological Survey of New South Wales, Sydney ; the Curator of the Bath Museum (England), and the Department of Agriculture and Technical Instruction, Dublin, have given useful and valuable information which is gratefully acknowledged.

The task has proved most interesting and instructive to me, and has suggested many problems and possibilities, so that it is hoped that in the near future it may be possible to amplify the present list.

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(v.) **Campbell, W. D.** The Irwin River Coalfield, Bulletin 38.

NOTE.—Figured specimens are indicated by capital letters in the column of References throughout the Tables.

PART I.

PALÆOZOIC FOSSILS.

The greater portion of Western Australia consists of Igneous or Metamorphic rocks of great antiquity, but in the "Kimberleys," the "North-West" to the "Gascoyne," large stretches of country consist of Palæozoic Rocks which have been recognised by most competent authorities as being chiefly of Carboniferous Age. A strip, running down between the Darling Ranges and the coast, is met with in the Victoria District, and may possibly be exposed at Bullsbrook, near Midland Junction, and further South along the

base of the Darling Ranges, but of this no definite Palæontologica evidence has yet been discovered. Still further South the Collie Coal Basin is the extreme outpost of the beds of this coal-bearing age so far as is yet known.

As regards Devonian Rocks, there is but very scanty information. Hardman (1) recognised Devonian strata in the Kimberley area and obtained fossils which are true Devonian types

In 1906, Mr. H. P. Woodward, in the course of an extended trip in the West Kimberley District, collected a number of specimens from the Barker Gorge in the Napier Range, which London authorities have classified as of undoubted Devonian age.

Some of the older writers, Hudleston, etc., determined possible Devonian forms from the "Gascoyne" and the "Irwin" localities, which the latter researches of this Department have failed to verify.

Rocks of greater antiquity are present in Western Australia, for Hardman obtained undoubted Cambrian fossils from Kimberley, but our knowledge is very restricted as it is not even definitely known where Hardman collected his specimens. It is also supposed that the Stirling Ranges in the extreme South of the State are Silurian and, according to Hardman, that Lower Silurian, or Cambro-Silurian strata, are exposed in the country he examined in the North. It is needless to enter more fully into the matter here as all information can be obtained from Bulletin 26, part 7, of 1907, where the Government Geologist goes into the Geology of the State in detail.

The lithological character of the Palæozoic rocks is not striking, the Carboniferous representations are mainly grey crystalline limestone with occasional ironstained areas, but associated with these are carbonaceous and micaceous shales, sandstones and conglomerates, as well as Glacial beds and series of volcanic lavas and ashes. The Nullagine Beds may be either Cambrian or Devonian: they are not Carboniferous. The Devonian Beds are mostly grey limestones, whilst the older Palæozoic strata consist chiefly of more or less altered sedimentary rocks and crystalline limestones. For further information in this connection reference may be made to the publication of this Department, to which attention has just been drawn.

In the following portion of the list the pages have been divided into four main columns, as explained in the Introduction.

Locality.—Roughly speaking there are four chief districts, Kimberley, Gascoyne, Irwin and Collie. Of these, the second is subdivided into the Valleys of the Lyons, Wyndham, Gascoyne,

(1.) Hardman: "Report on the Geology of the Kimberley District" (two reports), dated 1884 and 1885.

and Wooramel Rivers ; whilst the third is split up into Irwin River Coal seam and Mingenew.

It has been thought advisable to consider Mingenew as one of the more important sections, as it is chiefly there that fossils homotaxial with the Permo-Carboniferous of the Eastern States have been obtained. (1.)

(1.) *Vide* G.S., W.A., Bulletin No. 27, page 19.

PALEOZOIC.

CAMBRIAN.

	Genus and Species.	Locality.				Reference.	Exhibited.					
		Kimberley.					Geol. Surv. Museum.	Australian Museum.	Victorian Museum.	Dept. of Mines, N.S.W. Museum.	British Museum.	Geol. Soc. Lond. Museum.
	Sub-Kingdom MOLLUSCA. Class Gastropoda. Sub-Class Euthyneura. Order Opisthobranchia. Sub-Order Conularida.											
W	**Salterella Hardmani** (Eth. fil.)	×	..	..	..	I.o.r. ..	×	×	..	..	×	..
	Sub-Kingdom ARTHROPODA Class Crustacea. Sub-Class Trilobita. Order Opisthoparia.											
W	Olenellus (?) Forresti (Eth. fil.)	×	..	..	..	I.o.r. ..	..	..	..	..	×	..

DEVONIAN.

	Genus and Species.	Locality.			Reference.	Exhibited.					
		Kimberley.	Barker Gorge, Napier Range.	Gascoyne River.		Geol. Surv. Museum.	Australian Museum.	Victorian Museum.	Dept. of Mines, N.S.W. Museum.	British Museum.	Geol. Soc. Lond. Museum.
	Sub-Kingdom COELENTERATA. Sub-Branch Cnidaria. Class Hydrozoa. Stromatoporoidea.										
	Actinostroma clathratum (Nich.)	×	..	..	I.o. ..	..	..	..	..	×	..
(?)	Stromatoporella Eifeliensis (Nich.)	×	..	×	I.o. ..	..	..	..	..	×	..
	Class Anthozoa. Sub-class Tetracoralla.										
(?)	Cyathophyllum depressum (Hinde)	×	..	×	I.o. ..	..	..	..	.	×	..
	„ **virgatum** (Hinde)	×	..	×	I.o. ..	×	..	..	..	×	..
(?)	**Phillipsastræa (Smithia) sp.**	..	×	..	t. ..	×	..	..	..	..	..
	Sub-Class Hexacoralla. Order Madreporaria. Sub-Order Tabulata.										
	Aulopora repens (Knorr & Walch)	×	..	..	I.o. ..	..	.	..	..	×	..
	Favosites Goldfussi (Edw. & Haime) (1)	×	..	×	.. ..	×	..	..	..	..	..
	Pachypora tumida (Hinde)	×	..	..	I.o. ..	..	..	..	..	..	..
	„ **sp.**	..	×	..	t. ..	×	..	..	..	..	..
(?)	**Syringopora reticulata** var. **patula** (Hinde)	..	..	×	.. ..	×	..	..	.	×	..

	Sub-Kingdom ECHINODERMATA. Sub-Branch Pelmatozoa. Class Crinoidea.												
	Stems and arms of Crinoids	×	..	×	..	i. ..	×	..	..	..	..	..	
	Sub-Kingdom VERMES. Sub-Order Tubicola (Sedentaria.)												
(?)	*Spirorbis omphalodes* (Goldf.)	×	..	×	..	i.o. ..	..	..	..	..	..	..	
	Sub-Kingdom MOLLUSCOIDEA. Class Brachiopoda. Order Protremata.												
	Productus *sp.*	×	..	..	..	.. ..	×	..	..	..	..	..	
	Order Telotremata.												
W	**Atrypa reticularis** (Linné)	×	..	..	..	l.o.r. ..	×	..	..	..	×	..	
	Rhynchonella cuboides (J. de C. Sowerby)..	×	..	.	..	l.o. ..	×	..	..	..	×	..	
W	,, (**Hypothyris**) **pugnus** (Martin)	×	..	..	..	l.o.r. ..	×	..	..	..	×	..	
	,, (**Uncinulus**) *c.f.* **Timorensis** (Beyr.)	..	×	..	..	r. ..	×	..	..	..	..	..	
	Spirifera Musakheylensis *var.* **Australis** (Foord)	×	..	..	..	.. ..	×	..	..	..	.	..	
(?)	,, *c.f.* Verneuili (Murch)	×	.	..	..	.. ..	..	.	..	..	×	..	
	,, sp.	×	..	..	..	l.o.r. ..	..	..	..	..	×	..	
	Sub-Kingdom MOLLUSCA. Class Pelecypoda. Order Prionodesmacea.												

	Genus and Species.	Locality.				Reference.		Exhibited.						
		Kimberley.	Barker Gorge, Napier Range.	Gascoyne River.				Geol. Surv. Museum.	Australian Museum.	Victorian Museum.	Dept. of Mines, N.S.W. Museum.	British Museum.	Geol. Soc. Lond. Museum.	
	Class Gastropoda. Sub-Class Streptoneura. Order Aspidobranchia. Sub-Order Rhipidoglossa.													
	Euomphalus sp.	..	×	..	..	..	..	×	..	..	..	..	..	
	Loxonema sp.	..	×	..	..	..	..	×	..	..	..	..	..	
	Class Cephalopoda. Sub-Class Tetrabranchia. Order Nautiloidea. Sub-Order Orthochoanites.													
	Goniatites (Brancoceras) *c.f.* **rotatorius** (De Kon.)	×	..	..	..	..	..	×		..	..	..	..	
W	„ **sp.**	×	×	..	..	I.o.r.	..	×	..	..	..	..	..	
W	*Orthoceros spp*	×	..	..	..	I.o.r.	..	..	..	..	..	..	..	
	Sub-Kingdom ARTHROPODA. Class Crustacea. Sub-Class Trilobita. Order Opisthoparia.													
	Proetus *sp. nov.*	..	×	..	..	t.	..	×	..	..	..	..	..	

NOTE.—A fragment of bone of a coccostean fish was found associated with these Barker Gorge fossils, but it was too fragmentary to permit Dr. A. Smith-Woodward, F.R.S., to whom the specimen was submitted, to say more than that it belonged to a Coccostean fish, probably a new species allied to Coccosteus, and a new record for Australia.

CARBONIFEROUS.

	Genus and Species.	Locality											Reference.	Exhibited.						
	Sub-Kingdom PROTOZOA. Class Rhizopoda. Order Foraminifera. Sub-Order Porcellanea.	Kimberley.	Gascoyne.	Minilya River.	Lyons River.	Wyndham River.	Gascoyne River.	Wooramel River.	Irwin.	Irwin River Coal.	Mingenew P.C.	Collie Coalfield.		Geol. Surv. Museum.	Australian Museum.	Victorian Museum.	Dept. of Mines, N.S.W. Museum.	British Museum.	Geol. Soc. Lond. Museum.
*	Cornuspira Schlumbergi (Howchin)	..	..	..	..	..	..	..	×	×	..	..	k.M. ..	..	..	..	..	..	..
*	**Nubecularia Stephensi** (Howchin)	..	..	..	..	..	..	..	×	×	..	..	k.M.r.S.v.	×	×	..	..	..	..
	Sub-Order Vitro-Calcarea.																		
	Bulimina (?) sp.	..	..	..	..	..	..	..	..	..	..	×	n.r.S. ..	..	..	×	..	..	..
	Endothyra (?) sp.	..	..	..	..	..	..	..	..	..	..	×	n.r.S. ..	..	..	×	..	..	..
*	Frondicularia Woodwardi (Howchin)	..	..	..	..	..	..	..	×	×	..	..	k.M. ..	..	..	..	..	..	..
*	Nodosaria Irwinensis (Howchin)	..	..	..	..	..	..	..	×	×	..	..	k.M. ..	..	..	..	..	..	..
	Pulvinulina exigua (?) (Brady)	..	..	..	..	..	..	..	..	..	..	×	n.r.S. ..	..	..	×	..	..	..
	Truncatulina Haidingeri (D'Orb.)	..	..	..	..	..	..	..	..	..	..	×	n r.S. ..	..	..	×	..	..	..
	Valvulina plicata (Brady) ..	..	..	..	..	..	..	..	..	..	..	×	n.r.S. ..	..	..	×	..	..	..

* These species are represented in the collection of Mr. Walter Howchin of the Adelaide University.

	Genus and Species.	Locality.											Reference.	Exhibited.						
		Kimberley.	Gascoyne.	Minilya River.	Lyons River.	Wyndham River.	Gascoyne River.	Wooramel River.	Irwin.	Irwin River Coal.	Mingenew P.C.	Collie Coalfield.		Geol. Surv. Museum.	Australian Museum.	Victorian Museum.	Dept. of Mines, N.S.W. Museum.	British Museum.	Geol. Soc. Lond. Museum.
	Sub-Kingdom COELENTERATA. Sub-Branch Cnidaria. Class Hydrozoa Stromatoporoidea.																			
W(?)	Actinostroma clathratum (Nich.)	×	..	..	..	..	..	..	..	..	..	..	I. ..	..	..	..	..	×	..
	Stromatopora concentrica (Goldf.)	×	..	..	..	..	..	..	..	..	..	..	e.o.r. ..	..	..	..	..	..	..
	,, *placenta* (Phil.)	×	..	..	..	..	..	..	..	..	..	..	e.o.r. ..	..	..	..	..	..	..
	,, *sp.*	×	..	..	..	..	..	..	..	..	..	..	e. ..	..	..	..	..	..	..
W(?)	Stromatoporella Eifeliensis (Nich.)	..	×	..	..	..	..	..	..	..	..	..	I. ..	..	..	..	..	×	..
	Class Anthozoa. Sub-Class Tetracoralla.																			
W	*Amplexus nodulosus* (Phil.) ..	..	×	..	×	..	..	..	..	..	..	..	d.o. ..	..	..	..	..	..	..
W	,, **pustulosus** (Hudl.) ..	..	×	×	×	..	×	..	×	..	..	..	D.I.n.o.p.	×	..	..	×	×	..
	,, **Selwyni** (de Kon.) ..	..	..	..	..	..	..	..	×	..	..	..	.. ..	×	..	..	..	..	..
W	**Cyathophyllum depressum** (Hinde)	×	×	..	..	..	..	..	..	..	..	..	I.o.r. ..	×	..	..	..	..	..
W	,, **virgatum** (Hinde)	×	×	..	..	..	..	..	..	..	..	..	I.o.r. ..	×	..	..	..	..	..
	,, *sp.* ..	×	..	..	..	..	..	..	..	..	..	..	d.e.o.r...	..	..	..	..	..	..

	Lithostrotion (*Lithodendron*) *affine* (Flem.)	×	..	..	..	..	..	..	..	..	..	..	e.o.r. ..	..	..	..	..	..	..
	,, *sp.*	×	..	..	..	..	..	..	..	..	..	..	e. ..	..	..	..	..	..	..
W	**Pleurophyllum** (1) **Australe** (Hinde)	..	×	×	..	×	×	..	×	×	..	..	I.j.n.o.p.r.S.	×	×	..	×	×	..
W	,, **sulcatum** (Hinde)	..	×	..	..	..	×	..	×	×	..	..	I.j.o.s. ..	×	..	..	×	..	..
W	**Zaphrentis** *sp.*	×	×	..	×	..	..	..	..	..	..	..	d.e.o.r...	×	..	..	..	..	..
	Sub-Class Hexacoralla. Order Madreporaria. Sub-Order Tabulata.																		
W	**Alveolites obscurus** (de Kon.) ..	..	×	..	..	..	..	×	..	..	..	..	.. ..	×	..	..	..	..	..
	Chætetes tumidus (Phill.) ..	×	×	..	×	..	..	..	..	..	..	..	c.o.r. ..	..	..	..	..	..	..
	Favosites sp.	..	..	..	..	..	..	..	..	..	..	..	.. ..	..	..	..	..	..	..
W	**Hexagonella** (**Evactinopora**) **crucialis** (Hudl.)	×	×	..	×	×	×	×	×	..	..	..	D.n.o.P.r.	×	×	..	×	..	..
W	,, ,, **dendroidea** (Hudl.)	×	×	..	×	×	×	×	×	..	..	..	D.I.n.p.r.	×	×	..	×	×	..
	,, ,, sp.	×	..	..	..	..	..	..	..	..	..	..	g. ..	..	..	..	(?)	..	..
W	*Pachypora tumida* (Hinde) ..	×	×	..	..	..	..	..	..	..	..	..	I.o.r. ..	..	..	..	..	..	..
	,, *sp. nov.*	..	×	..	×	..	..	..	..	..	..	..	d. ..	..	..	..	..	..	..
	,, **sp.**	×	×	..	×	..	..	..	..	..	..	..	.. ..	×	..	..	..	..	..
	Stenopora Leichardti (Nich. & Eth.)	..	..	..	..	..	..	..	×	..	..	..	o. ..	..	..	×	..	..	..
W	,, *Tasmaniensis* (Lonsd.)	×	×	..	×	..	×	..	..	..	..	..	d.e.o.r...	..	..	..	..	..	..
	,, sp.	×	..	..	..	..	..	..	..	..	..	..	g. ..	..	..	..	(?)	..	..
W	**Syringopora reticulata** *var.* **patula** (Hinde)	..	×	..	..	..	..	..	..	..	..	..	I.o.r. ..	×	..	..	..	..	..
	,, *sp.*	×	×	..	..	..	..	..	..	..	..	..	e.i.o.r. ..	..	..	..	..	..	..

(1) In the original article by Dr. G. J. Hinde the word is spelt Plerophyllum. All subsequent authorities quote the name as given in this list.

	Genus and Species.	Locality.											Reference.	Exhibited.						
	Sub-Kingdom ECHINODERMATA. Sub-Branch Pelmatozoa. Class Crinoidea. Order Larviformia.	Kimberley.	Gascoyne.	Minilya River.	Lyons River.	Wyndham River.	Gascoyne River.	Wooramel River.	Irwin.	Irwin River Coal.	Mingenew P.C.	Collie Coalfield.		Geol. Surv. Museum.	Australian Museum	Victorian Museum.	Dept. of Mines, N.S.W. Museum.	British Museum.	(Geol. Soc. Lond.) Museum.
	Symbathocrinus sp. (*fide* F. A. Bather)	..	..	..	..	..	..	..	×	..	..	..	.. ..	..	..	..	..	×	..
	Order Camerata.																		
	Actinocrinus (?) *sp.*	×	×	..	..	..	..	..	×	×	..	..	e.l.o.q.r.v.	×	..	×	..	..	..
	Platycrinus *sp.*	×	×	..	..	..	..	..	..	×	..	..	e.o.r.v...	×	..	..	..	..	..
W	*Poteriocrinus crassus* (Miller) ..	×	×	..	×	..	×	..	..	..	..	..	d.e.o.r...	..	..	..	..	..	..
	Rhodocrinus (?) *sp.*	×	×	..	..	..	..	..	..	..	..	..	l. ..	..	..	..	..	..	..
	Order Fistulata.																		
W	*Cyathocrinus sp.*	..	×	..	×	..	×	..	..	..	..	..	d.o. ..	..	..	..	..	..	..
	Crinoid head	..	×	..	..	×	..	..	..	..	..	..	.. ..	×	..	..	..	..	×
	.. **stems, etc.**	×	×	×	×	×	×	×	×	×	..	..	n.r.s.u.v.	×	×	×	×	×	×

	Class Blastoidea. **Order Regulares.**																			
	Pentremites sp.	×	..	..	..	..	..	..	..	..	..	..	e.o.r.	..	..	..	..	..	..	..
	Sub-Kingdom VERMES. **Sub-Order Tubicola (Sedentaria).**																			
	Serpula spp.	×	..	..	..	..	..	..	..	..	..	..	e.o.r.	..	..	..	..	..	..	..
	Spirorbis ambiguus (Flem.) ..	..	×	..	..	×	..	..	..	..	..	..	P.	..	×	..	..	..	..	..
(?)	,, *omphalodes* (Goldf.)	..	×	..	..	..	..	..	..	..	..	..	i.	..	..	..	..	..	..	..
	,, *spp.*	×	..	..	..	..	..	..	..	..	..	..	e.o.r.	..	..	..	..	..	..	..
	Sub-Kingdom MOLLUSCOIDEA. **Class Bryozoa. Order Gymnolæmata.** **Sub-Order Cyclostomata.**																			
	Ceriopora sp.	×	..	..	..	..	..	..	..	..	..	..	e.o.r.	..	..	..	..	..	..	..
	Sub-Order Cryptostomata.																			
W	**Fenestella plebeia** (McCoy))	×	×	..	×	..	×	..	×	×	..	..	d.e.o.r.S.v.	×	..	..	..	..	..	..
	,, **fossula** (Lonsd.))																			
	,, **plebeia** *var.* **densa** (Ethfil.)	..	..	..	..	..	..	..	..	..	×	..	.. ..	×	..	..	..	..	..	..
	,, **spp.**	×	×	..	..	..	×	×	×	×	..	..	o.r.	..	×	..	..	..	..	..
W	**Polypora Australis** (Hinde) ..	..	×	..	..	..	..	..	..	..	..	..	I.o.	..	×	..	..	..	..	..
W	**Protoretepora ampla** (Lonsd.) ..	..	×	..	×	..	×	×	×	×	×	..	d.i.o.	..	×	..	..	..	..	..
	,, *antiqua* (Lonsd.)	×	×	..	..	..	..	..	..	..	..	..	e.	..	..	..	..	..	..	..
W	Rhombopora tenuis (Hinde) ..	..	×	..	..	×	×	..	..	..	..	..	I.n.o.r.u.	..	..	..	..	×	..	..

	Genus and Species.	Locality.											Reference.	Exhibited.					
	Class Brachiopoda. Order Neotremata.	Kimberley.	Gascoyne.	Minilya River.	Lyons River.	Wyndham River.	Gascoyne River.	Woorramel River.	Irwin.	Irwin River Coal.	Mingenew P.C.	Collie Coalfield.		Geol. Surv. Museum.	Australian Museum	Victorian Museum.	Dept. of Mines, N.S.W. Museum.	British Museum.	Geol. Soc. Lond. Museum.
	Crania sp.	×	..	..	..	..	..	..	..	..	..	..	e. ..	..	..	..	..	..	..
	Discina sp.	×	..	..	..	..	..	..	..	..	..	..	e.o.r. ..	..	..	..	..	..	..
	Order Protremata.																		
	Aulosteges Baracoodensis (Eth. fil.)	..	×	..	..	..	×	×	×	×	..	..	n.P.r.u.v.	×	..	..	×	..	..
	Chonetes Hardrensis (Phil.) ..	×	..	..	..	..	..	..	..	..	..	..	e.o.r. ..	..	..	..	..	..	..
W	„ **Pratti** (Davidson) ..	..	×	×	×	×	×	..	×	×	..	..	J.n.o.p.r.S.u.v.	×	..	..	×	×	..
W	„ **spp.** (*non* **pratti**) ..	×	..	..	..	..	..	..	..	..	×	..	h.I.n.o.r.S.v.	×	..	..	(?)	×	×
	Derbyia sp. *c.f.* **senilis** (Phil.) (1)	..	..	..	..	..	..	..	×	×	..	..	q. ..	×	..	×	..	..	..
	Orthis resupinata (Martin) ..	×	..	..	..	..	..	..	..	..	..	..	e.o.r. ..	..	..	..	..	..	..
	„ *c.f.* **Michelini** (Martin) ..	..	×	..	..	..	..	×	..	..	..	..	.. ..	×	..	..	..	..	..

W	„ **spp.**	×	×	..	×	..	..	×	..	..	×	..	d.e. ..	×	..	..	..	..	..
W	**Orthotetes (Streptorhynchus)** (2) **senilis** (Phill.)	×	×	..	..	..	..	..	×	×	..	..	e.i.j.o.p.r.v	×	..	×	..	..	..
W	**Productus brachythærus** (Sowerby)	×	×	..	×	..	..	..	×	×	×	..	d.g.h.r.s.	×	×	..	(?)	..	..
	„ „ *var.* (Eth. fil.)	..	..	..	..	..	..	..	×	×	..	..	s. ..	×	..	..	..	..	..
	„ Cora (d'Orb.) ..	..	..	..	..	..	..	..	×	×	..	..	.. ..	..	..	×	..	..	..
	„ *c.f.* **Cora** (d'Orb.) ..	..	×	..	..	..	×	..	..	..	..	..	.. ..	×	..	..	×	..	..
	„ *giganteus* (Mart.) ..	×	..	..	..	..	..	..	..	..	..	..	e.o.r. ..	..	..	..	..	..	..
	„ *longispinus* (Sowerby)	×	..	..	..	..	..	..	..	..	..	..	e.o.r. ..	..	..	..	..	..	..
	„ *c.f.* **margaritaceus** (Phill.)	..	..	..	..	..	..	..	×	×	..	..	.. ..	×	..	..	..	..	..
	„ **scabriculus** (Mart.) ..	..	..	..	..	..	..	..	×	×	..	..	.. ..	×	..	..	..	..	..
	„ **semireticulatus** (Mart.)	×	×	×	×	×	×	..	×	×	..	..	e.n.o.P.r. s.u.v.	×	..	..	×	..	..
	„ „ *var.* **pugilis** (Phill.)&	..	..	..	..	..	..	..	×	..	..	..	.. ..	×	..	..	..	..	..
	„ *c.f.* **spiralis** (Waagen) and **subcostatus** (Waagen)	..	×	..	..	..	×	..	..	..	..	..	.. ..	×	..	..	..	..	..
W	„ **subquadratus** (Morris)	..	..	..	..	..	..	×	×	×	×	..	I.j.n.o.r. S.v.	×	×	..	×	×	..
W	„ **tenuistriatus** (De Vern.)	..	×	..	..	×	..	..	×	×	..	..	I.j.o.r.s.u.	×	×	..	×	×	..
	„ „ *var.* **Foordi** (Eth. fil.)	..	×	..	..	×	..	..	×	×	..	..	n.P.r.S.v.	×	×	..	..	..	..
W	„ **undatus** (Defr.) ..	..	×	..	..	..	..	..	×	×	..	..	I.j.o.q.r.s. v.	×	×	×	×	×	..
	„ **spp.**	×	×	..	×	..	×	..	×	×	..	..	d.e.g.n.u.v.	×	..	..	(?)	..	×
	Strophalosia Clarkei (Eth. fil.)	×	×	×	..	..	..	..	×	×	..	..	I.n.o.q.r.	×	..	×	..	×	..
	„ *c.f.* Gerardi (King)	..	..	..	..	..	..	..	×	..	..	..	h. ..	..	..	..	(?)	..	..
	„ **sp.**	..	×	×	×	..	..	..	..	..	..	..	d.P. ..	×	×	..	..	..	..
	Strophomena **analoga** (Phil.) ..	..	..	..	..	..	..	..	×	..	..	..	h. ..	×	..	..	(?)	..	..
	„ **sp.**	..	×	×	..	..	..	..	×	×	..	..	u.v. ..	×	..	..	..	..	..

	Genus and Species.	Locality.											Reference.	Exhibited.					
	Order Telotremata.	Kimberley.	Gascoyne.	Minilya River.	Lyons River.	Wyndham River.	Gascoyne River.	Woorramel River.	Irwin.	Irwin River Coal.	Mingenew P.C.	Collie Coalfield.		Geol. Surv. Museum.	Australian Museum.	Victorian Museum.	Dept. of Mines, N.S.W. Museum.	British Museum.	Geol. Soc. Lond. Museum.
	Actinoconchus *c.f.* **planosulcatus** (Phill.)	..	..	..	..	..	..	..	×	×	..	..	.. ..	×	..	..	..	..	..
	„ **sp.** (*or* **Cleiothyris** sp.)	..	..	..	..	..	..	..	×	×	..	..	.. ..	×	..	..	..	..	..
	Atrypa sp.	×	..	..	..	..	..	..	..	..	..	..	e.						
	„ (?) **sp.**	..	..	..	..	..	..	..	×	..	..	..	.. ..	×	..	..	..	..	..
	Athyris ambigua (Sowerby) ..	×	..	..	..	..	..	..	..	..	..	..	e. ..	×	..	..	..	..	..
	„ **sp.**	..	×	..	×	..	..	..	..	..	..	..	u. ..	×	..	..	..	..	..
W	**Cleiothyris (Athyris) Macleayana** (Eth. fil.)	×	×	×	..	×	×	×	×	×	×	..	G.I.n.o.P. r.s.u.v.	×	×	..	×	×	..
	„ „ *var.* **Baracoodensis** (Eth. fil.)	..	×	..	..	..	×	..	..	..	..	..	P. ..	×	×	..	..	..	..
	„ „ **sp.** *near* **Macleayana** (Eth. fil.)	..	..	..	..	..	..	..	×	×	..	..	.. ..	×	..	..	..	..	..
W	„ „ **Roysii** (Lev.)	..	×	..	×	..	..	×	..	..	..	..	d.o. ..	×	..	..	..	..	..
	„ „ **sp.** ..	×	..	..	..	..	..	..	×	..	..	..	e.n. ..	×	..	..	..	..	..

	Cyrtina carbonaria *var.* **Australasica** (Eth. fil.)	×	..	..	..	..	..	..	..	..	×	..	(l.n.r.s.v.	×	..	..	(?)	..	..
	Dielasma (Terebratula) nobilis (Eth. fil.)	..	..	..	..	..	..	..	..	..	×	..	n.r.S.v.	×	×	..	..	..	..
	„ „ **sacculus** (Martin)	×	..	..	..	..	..	..	..	..	..	..	e.o.r. ..	×	..	..	..	..	..
	„ „ **hastata** (Sowerby)	×	..	..	..	..	..	..	..	..	×	..	e.o.r.v...	×	..	..	..	..	..
	„ „ **amygdala** (Dana) (?)	..	..	..	..	..	..	..	..	..	×	..	.. ..	×	..	..	..	..	..
	„ „ **cymbæformis** (Morris) (?)	..	..	..	..	..	..	..	..	..	×	..	.. ..	×	..	..	..	..	..
	„ „ „ **var** (?)	..	..	..	..	..	..	..	..	..	×	..	.. ..	×	..	..	..	..	..
	„ „ **sp.** ..	×	×	..	..	..	×	×	×	×	×	..	e.r.S.u.v.	×	..	..	..	..	..
	„ „ **sp. ind.**	..	×	..	..	..	×	..	..	..	..	..	n.r. ..	×	..	..	..	..	..
W	**Reticularia crebristria** (Morris)..	..	..	..	..	..	..	..	×	..	..	..	i.j.o.v. ..	×	..	..	..	..	..
W	„ **lineata** (Martin) ..	..	×	..	..	×	..	..	×	×	..	..	i.j.n.o.p.r. s.u.v.	×	..	..	×	..	..
	Retzia sp.	..	..	..	..	..	..	..	×	..	..	..	.. ..	×	..	..	..	..	..
	Rhynchonella (Hypothyris) cuboides (J. de C. Sowerby.)	×	..	..	..	..	..	..	..	..	..	..	e.o.r. ..	×	..	..	..	..	..
	„ „ **pleurodon** (Phill.)	×	..	..	..	..	..	..	×	..	..	..	e.o.r. ..	×	..	..	..	..	..
	„ „ **pugnus** (Mart.)	×	..	..	..	..	..	..	..	..	..	..	e.o.r. ..	×	..	..	..	..	..
	Seminula subtilita (Hall) (?) ..	×	×	..	..	..	×	..	×	×	..	..	P.r.S.v.	×	×	×	..	..	..
	„ **sp.**	..	×	..	..	..	×	..	..	..	..	..	.. ..	×	..	..	..	..	..
	Spirifera avicula (Sowerby) ..	..	..	..	..	..	..	..	..	..	×	..	r. ..	×	×	..	..	..	..
W	„ **convoluta** (Phill.) ..	..	×	..	..	..	×	×	×	..	..	..	.. ..	×	..	..	×	..	..
	„ *c.f.* **convoluta** (Phill.)	..	×	..	..	..	×	..	×	..	..	..	d.o. ..	×	..	×	..	..	..
W	„ *c.f.* **crassus** (De Kon.)	..	×	..	×	..	×	..	..	..	..	..	d.o. ..	×	..	..	..	..	..
	„ **disjuncta** (Sowerby) ..	..	..	..	..	..	..	..	×	×	..	..	.. ..	..	..	..	..	..	×
	„ (**Martinia**) **glabra** (Martin)	..	..	..	..	..	..	..	×	×	..	..	.. ..	×	..	..	..	..	..

	Genus and Species.	Locality.											Reference.	Exhibited.					
	Order Telotremata—*continued.*	Kimberley.	Gascoyne.	Minilya River.	Lyons River.	Wyndham River.	Gascoyne River.	Wooramel River.	Irwin.	Irwin River Coal.	Mingenew P.C.	Collie Coalfield.		Geol. Surv. Museum.	Australian Museum.	Victorian Museum.	Dept. of Mines, N.S.W. Museum.	British Museum.	Geol. Soc. Lond. Museum.
W	**Spirifera Hardmani** (Foord) ..	×	×	..	..	×	×	..	×	×	..	..	I.n.o.P.r. u.v.	×	×	..	×	×	..
W	„ **Kimberleyensis** (Foord)	..	×	..	..	..	×	..	×	..	..	..	I.o. ..	×	..	..	..	..	..
W	„ **lata** (McCoy) ..	..	×	..	×	×	×	×	×	..	..	..	I n.o.r.u.v.	×	..	..	..	..	..
	„ „ **var.** with ribbed sulcus	..	×	..	..	×	..	..	..	..	..	..	P. ..	×	..	..	..	..	..
W	„ **Musakheylensis** *var.* **Australis** (Foord)	..	×	..	..	×	×	×	×	×	..	..	I.j.n.o.P.r. u.v.	×	×	..	..	..	..
W	„ **striata** (Martin) ..	×	×	..	×	×	×	..	..	..	..	..	d.e.o. ..	×	..	..	..	..	..
	„ *c.f.* **striata** (Martin) ..	..	..	..	..	..	..	..	×	..	..	..	.. ..	×	..	..	×	..	..
	„ **Stutchburyi** (?) (Eth. fil.)	..	..	..	..	..	..	..	..	..	×	..	p. ..	×	×	..	..	..	..
	„ (Martinopsis) subradiata (Sowerby)	..	×	..	..	..	..	..	..	..	..	..	.. ..	..	..	×	..	..	..
	„ **trigonalis** (Martin) ..	..	×	..	×	..	×	×	×	×	..	..	.. ..	×	..	..	×	..	×
W	„ **vespertilio** (G. Sowerby)	..	×	..	..	..	×	..	..	..	..	..	d.o. (?)	×	..	..	..	..	..
	„ **spp.**	×	×	..	..	×	×	×	×	×	×	..	e.g.n.P.r. S.u.v.	×	×	..	(?)	..	..
	„ **sp.** (*or* **Martinopsis sp.**)	×	..	..	..	..	..	..	×	..	..	..	.. ..	×	..	..	..	..	..
W	**Syringothyris exsuperans** (De Kon.)	..	×	..	..	..	×	..	×	×	..	..	j.j.o.v. ..	×	..	×	×	×	..

	Sub-Kingdom Mollusca. Class Pelecypoda. Order Prionodesmacea.																			
	Anthracoptera sp.	..	×	..	..	..	×	..	..	..	..	..	r.u. ..	×	×	..	..	..	..
	Arca (?) sp.	..	..	..	..	..	..	..	×	×	..	..	.. ..	×	..	..	..	..	..
	Aviculopecten granosus (J. de C. Sowerby.)	×	..	..	..	..	..	..	..	..	..	..	e. ..	..	..	..	..	..	..
	„ **multiradiata** (Eth. sen.)	..	×	..	..	..	..	..	..	..	..	..	.. ..	×	..	..	..	..	..
	„ **Sprenti** (Johnst.)	..	..	..	..	..	..	..	×	×	..	..	r.S.v. ..	×	×	..	..	..	..
W	„ **tenuicollis** (Dana)	×	×	×	..	×	×	..	×	×	..	..	g.I.P.r.u.v	×	..	..	..	×	..
	„ **spp.**	..	×	×	..	×	×	×	×	×	×	..	e.h.i.n.o.r. S.v.	×	..	..	..	..	..
	Cardiomorpha oblonga (Sowerby)	×	..	..	..	..	..	..	..	..	..	..	e. ..	..	..	..	..	..	..
	Chænomya (?) sp.	..	..	..	..	..	..	..	×	×	..	..	.. ..	×	..	..	..	..	..
	Conocardiam (Pleurorhynchus) sp.	×	..	..	..	..	..	..	×	×	..	..	e.r.s.v.	×	..	..	..	..	..
	„ „ **(?) sp.**	..	..	..	..	..	..	..	×	×	..	..	.. ..	×	..	..	..	..	..
	Conocardiam Hibernicum (?) (Sowerby)	×	..	..	..	..	..	..	..	..	..	..	e. ..	..	..	..	..	..	..
W	**Deltopecten (Aviculopecten) Illawarensis** (Morris) (?)	..	×	..	..	..	×	×	..	..	..	..	d.o. ..	×	..	..	..	..	..
	„ „ **leniusculus** (Dana)	..	×	..	..	..	..	..	..	..	..	..	.. ..	×	..	..	..	..	..
W	„ „ **limæformis** (Morris)	..	×	..	×	..	×	..	..	..	..	..	d.o. ..	×	..	..	..	..	..
	„ „ **subquinque lineatus** (McCoy)	..	..	..	..	..	..	..	..	..	×	..	n.r.S.v.	×	×	..	..	..	..
	„ „ **spp.**	..	..	..	..	..	..	..	..	×	×	..	h. ..	×	..	..	× (?)	..	..
W	**Edmondia spp.**	×	..	..	..	..	..	..	×	×	×	..	g.i.o.v.	×	..	..	..	..	..
W	**Modiola spp.**	×	..	..	..	..	..	..	×	×	×	..	i.n.o.r.S.v	×	..	..	..	..	..
	Myalina (?) Mingenewensis (Eth. fil.)	..	..	..	..	..	..	..	..	..	×	..	n.r.S.v.	×	×	..	..	..	..
	„ **spp.**	..	×	..	..	..	×	×	..	..	×	..	.. ..	×	×	..	..	..	..
	Mytilops (?) sp.	..	..	..	..	..	..	..	..	..	×	..	.. ..	×	..	..	..	..	..

	Genus and Species.	Locality.											Reference.	Exhibited.						
	Order Prionodesmacea—*contd.*	Kimberley.	Gascoyne.	Minilya River.	Lyons River.	Wyndham River.	Gascoyne River.	Woorinel River.	Irwin.	Irwin River Coal.	Mingenew P.C.	Collie Coalfield.		Geol. Surv. Museum.	Australian Museum	Victorian Museum.	Dept. of Mines, N.S.W. Museum.	British Museum.	Geol. Soc. Lond. Museum.
W	**Mytilus** spp.	×	..	..	..	..	..	..	..	..	×	..	e. ..	×	..	..	..	..	..
	„ **sp.** (*or* **Modiomorpha**)	..	..	..	..	..	..	..	..	..	×	..	.. ..	×	×	..	..	..	..
	Parallelodon (**Palæarca**) **subarguta** (De Kon.)	×	..	..	..	..	..	..	×	..	..	..	g.h. ..	×	..	..	(?)	..	..
	„ **sp.** (**Macrodon sp.**)	..	..	..	..	..	..	..	×	..	..	..	.. ..	×	..	..	..	..	..
	Pterinea (Merismoptera) macroptera (Morris)	×	..	..	..	..	..	..	..	..	..	..	g. ..	..	..	..	(?)	..	..
	Sanguinolites *c.f.* Hibernicus (Hind)	..	..	..	..	..	..	..	×	..	..	..	q. ..	..	..	×	..	..	..
	„ **sp.**	..	..	..	..	..	..	..	×	×	×	..	i.o.v. ..	×	..	..	..	..	..
	Stutchburia *c.f.* **Randsi** (Eth. fil.)	..	..	..	..	..	..	..	..	×	..	..	v. ..	×	..	..	..	..	..
	„ **sp.**	..	..	..	..	..	..	..	..	×	..	..	r.S.v. ..	×	..	..	..	..	..
	Order Anomalodesmacea.																		
	Allorisma *c.f.* curvatum (Morris)	..	..	..	..	..	..	..	×	..	..	..	q. ..	..	..	×	..	..	..
	„ *c.f.* maximum (Portl.)	..	..	..	..	..	..	..	×	..	..	..	q. ..	..	..	×	..	..	..

	Order Teleodesmacea.																		
	Curtonotus elegans (Salter) ..	×	..	..	..	..	..	..	..	..	..	..	e. ..	..	..	..	..	..	..
W	**Pleurophorus (Pachydomus) carinatus** (1) (Morris)	..	×	..	..	..	..	×	×	..	..	..	i.j.o. ..	×	..	..	..	..	..
	„ „ **spp.**	×	..	..	..	..	..	..	×	..	..	..	g.h.v. ..	×	×	..	(?)	..	..
	Class Gastropoda. Sub-Class Streptoneura. Order Aspidobranchia. Sub-Order Rhipidoglossa.																		
	Baylea (Ivania) Levellii (De Kon.)	..	..	..	..	..	..	..	×	..	..	..	.. ..	×	..	..	..	..	..
	Bellerophon costatus (J. de C. Sowerby)	..	..	..	..	..	..	..	×	×	..	..	r.S.v. ..	×	..	..	..	..	..
W	„ **decussatus** (Flem.) (?)	..	..	..	..	..	..	..	×	..	..	..	i.j.o. ..	×	..	..	..	..	..
	„ *Urei* (Flem.)	×	..	..	..	..	..	..	..	..	..	..	*e.* ..	..	..	..	..	..	..
	„ **sp.**	×	..	..	..	..	..	..	×	×	..	..	e.v. ..	×	..	..	..	..	..
W	**Euomphalus spp.**	×	..	..	..	..	..	..	×	..	..	..	v. ..	×	..	..	..	..	..
	„ (?) **spp.**	×	..	..	..	..	..	..	×	..	..	..	I. ..	×	..	..	..	×	..
	Euphemus Orbignii (Portl.) ..	×	..	..	..	..	..	..	..	..	..	..	g. ..	..	..	..	(?)	..	..
	Mourlonia (Pleurotomaria) humilis (De Kon.)	×	..	..	..	..	..	..	..	..	..	..	g. ..	..	..	..	(?)	..	..
	Pleurotomaria spp.	×	..	..	..	..	..	..	..	×	..	..	e.o.r.v...	×	..	..	..	..	×
W	„ (?) **sp.** ..	×	..	..	..	..	..	..	..	..	..	..	e.I.o.r...	..	..	..	..	×	..
	Ptychomphalina Maitlandi (Eth. fil.)	..	×	×	..	..	..	..	..	..	×	..	n.P.u. ..	×	..	..	..	..	..
	„ **sp.**	..	..	..	..	..	..	..	..	..	×	..	.. ..	×	..	..	..	..	..

(1) Or Mœonia carinata (Morris) fide Eth. fil. Geol. and Pal., Queensl., p. 283.

	Genus and Species.	Locality.											Reference.	Exhibited.					
	Order Ctenobranchia. Sub-Order Platypoda.	Kimberley.	Gascoyne.	Minilya River.	Lyons River.	Wyndham River.	Gascoyne River.	Wooramel River.	Irwin.	Irwin River Coal.	Mingenew P.C.	Collie Coalfield.		Geol. Surv. Museum.	Australian Museum	Victorian Museum.	Dept. of Mines, N.S.W. Museum.	British Museum.	Geol. Soc. Lond. Museum.
	Acroculia (Platyceras) sp. ..	..	..	..	..	..	..	..	×	×	..	..	v. ..	×	..	..	..	..	..
	Loxonema sp.	×	..	..	..	..	..	..	..	..	..	..	e.o.r. ..	..	..	..	..	..	..
	Natica sp.	×	..	..	..	..	..	..	..	..	..	..	e.o.r. ..	..	..	..	..	..	..
	Class Cephalopoda. Sub-Class Tetrabranchiata. Order Nautiloidea. Sub-Order Orthochoanites.																		
	Cæloanutilus Chesterensis (De Kon.)	..	..	..	..	..	..	..	..	×	..	..	.. ..	×	..	..	..	..	..
W	**Discites** *c.f.* **Omalianus** (De Kon.)	..	..	..	..	..	..	..	×	..	..	..	i.j.o. ..	×	..	..	..	..	..
	,, **sp.**	..	..	..	..	..	..	..	×	..	..	..	i.j.o. ..	×	..	..	..	..	..
	Nautilus (?) sp. (*Mesozoic ?*) ..	..	..	..	..	..	..	..	..	×	..	..	.. ..	..	..	..	..	..	×
W	**Orthoceras spp.**	×	..	..	..	..	..	..	×	×	..	..	e.i.j.o.v.	×	..	..	..	×	..

	Sub-Order Cyrtoceratites.																						
	Actinoceras sp.	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Order Ammonoidea. Sub-Order Eurycampyli.																						
	Gastrioceras Jacksoni (Eth. fil.)	..	..	..	..	..	..	..	×	..	..	..	r.S.	..	×	..	..	..	..	..	..	..	..	..
	Glyphioceras sphæricum (Goldf.)	×	..	..	..	..	..	..	..	..	..	..	e.	..	×	..	..	..	..	..	..	..	..	..
	„ **sp.**	×	..	..	..	..	..	..	..	..	..	..	e.	..	×	..	..	..	..	..	..	..	..	..
	„ (?) sp.	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..
	Sub-Order Phyllocampyli.																						
W	**Agathiceras micromphalum** (Morris)	×	..	..	..	..	..	..	×	..	..	..	I.q.	..	×	..	×	..	×	..				
	Sub-Order Pachycampyli.																						
	Brancoceras sp.	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	..			
	Sub-Kingdom ARTHROPODA. Class Crustacea. Sub-Class Trilobita. Order Opisthoparia.																						
	Phillipsia grandis (Eth. fil.) ..	..	×	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	×	..	..			

	Genus and Species.	Locality.											Reference.	Exhibited.					
	Super-Order Ostracoda.	Kimberley.	Gascoyne.	Minilya River.	Lyons River.	Wyndham River.	Gascoyne River.	Woolamel River.	Irwin.	Irwin River Coal.	Mingenew P.C.	Collie Coalfield.		Geol. Surv. Museum.	Australian Museum.	Victorian Museum.	Dept. of Mines, N.S.W. Museum.	British Museum.	Geol. Soc. Lond. Museum.
	Various species	..	×	..	..	..	×	..	..	..	..	..	.. ..	×	..	..	..	..	..
	Crustacean tracks (?)	..	×	×	..	..	..	..	..	..	..	..	n.P. ..	×	..	..	..	..	..
	VERTEBRATA. Class Pisces. Sub-Class Selachii.																		
W	**Edestus Davisii** (H. Woodw.) ..	..	×	..	..	..	×	..	..	..	..	..	F.o. ..	×	..	..	..	..	..
	Pœcilodus Jonesi (Ag.) ..	×	..	..	..	..	..	..	..	..	..	..	c. ..	..	..	..	..	..	..
	Small tooth	×	..	..	..	..	..	..	..	..	..	..	c.v. ..	×	..	..	..	..	..

PART II.

Mesozoic Fossils.

Rocks containing animal remains of Mesozoic age cover a fair percentage of the sedimentary area of the State. The beds consist for the most part of yellowish, reddish, or brownish ferruginous sandstones, occasionally containing a large amount of calcareous matter, and even passing into yellowish limestone bands that are highly crystalline and full of fossils, all showing a typically Jurassic facies. Naturally the sandstones, though often very fossiliferous, are not remarkable for the good state of preservation of the animal remains they contain. Still, numerous excellent specimens have been obtained by the officers of this Department and have been incorporated in the Geological Survey Collection, now on exhibit in the Geological Gallery of the Western Australian Museum.

One of the earliest geological observers in the colony, F. T. Gregory, reported the presence of the Cretaceous strata near Gin Gin, in the form of chalk, and records the collection of Ammonites, etc., from the beds, thus giving them a truly Mesozoic facies. Subsequent authorities seem to have placed little faith in this discovery, reported in the Q. J. G. S., Vol. XVI. 1861, pp. 475–483, especially as one of the Lamellibranchs (Pelecypods) was found to be a truly Jurassic form, *Trigonia Moorei* (Lycett). There seems little doubt, however, that these beds are homotaxial with the Cretaceous of Europe when the whole of the known Gingin fauna is considered. (*Vide* Article VIII., p. 115, *et. seq*).

In this portion of the list, the same general plan adopted in Part 1 has been followed, but it has been thought advisable to introduce a column for doubtful or vague localities which are distinguished as under :—

"Western Australia"	1
Champion Bay	2
Gascoyne River District	3

Genus and Species.	Locality.											Reference.	Exhibited.					
Sub-Kingdom PROTOZOA. Class Rhizopoda. Order Foraminifera.	Shark Bay.	Moresby Range.	Greenough R.	Tibradden.	Moonyoonooka.	Sandspring.	Woolanooka.	Snake Farm.	Mount Hill.	Doubtful Locs.		Geol. Surv. Museum.	Australian Museum	Victorian Museum.	Bath Museum.	British Museum.	Geol. Soc. Lond. Museum.
Bulimina Gregorii (Chapm.)	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
Cristellaria costata *var.* compressa (Chapm.)	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
„ „ *var.* seminuda (Chapm.)	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
„ cultrata *var.* radiata (Moore)	..	..	..	..	..	..	..	..	..	1	b.(c.)o.	..	..	..	×	..	..
„ Daintreei (Chapm.) ..	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
„ decipiens (Wisnow.) ..	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
„ *c.f.* limata (Schw.) ..	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
„ prominula (Reuss) ..	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
„ rotulata (Lamarck) ..	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
„ subalata (Reuss)	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
Discorbina rosacea (D'Orb.)	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
Flabellina dilatata (Wisnow.) ..	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
Haplophragmium neocomianum (Chapm.)	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
Marginulina compressa (D'Orb.) ..	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
„ solida (Terquem) ..	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
Polymorphina burdigalensis (D'Orb.) ..	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
„ compressa (D'Orb.) ..	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
„ gutta (D'Orb.) ..	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..

	Vaginulina intumescens (Reuss) ..	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
	„ lata (Corn.)	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
	„ Schloenbachi *var.* interrupta (Reuss)	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
	„ strigillata (Reuss.) ..	..	..	×	..	..	..	..	..	..	..	Q.	..	..	×	..	..	..
	Sub-Kingdom ECHINODERMATA. Sub-Branch Pelmatozoa. Class Crinoidea. Order Articulata.																	
	Pentacrinus spp.	..	×	..	..	..	..	..	..	..	1	b.	..	..	..	×	..	..
	Sub-Branch Echinozoa. Class Echinoidea.																	
W	*Spines of Echini*	..	..	..	..	..	..	..	..	..	1	b.	..	..	..	..	..	..
	Sub-Kingdom VERMES. Sub-Order Tubicola (Sedentaria).																	
	Serpula conformis (Goldf.)	..	..	..	×	..	..	..	..	..	..	T.	×	..	..	..	..	..
W	„ spp.	..	×	..	..	..	..	..	..	..	..	a.b.	..	..	..	×	..	..
	Sub-Kingdom MOLLUSCOIDEA. Class Bryozoa.																	
W	*Bryozoa*	×	×	..	..	..	..	..	..	..	..	b.	..	..	..	..	..	..

	Genus and Species.	Locality.										Reference.	Exhibited.					
	Class Brachiopoda. Order Telotremata.	Shark Bay.	Moresby Range.	Greenough R.	Tibradden.	Moonyoonooka.	Sandspring.	Woolanooka.	Snake Farm.	Mount Hill.	Doubtful Locs.		Geol. Surv. Museum.	Australian Museum.	Victorian Museum.	Bath Museum.	British Museum.	Geol. Soc. Lond. Museum.
W	**Rhynchonella variabilis** (Schl.) ..	×	×	..	..	×	..	..	×	×	1	a.B.c.o.T.	×	..	..	×	..	..
	„ *c.f.* solitaria (Moore) ..	..	×	..	..	..	..	..	..	..	..	.. ..	..	..	×	..	..	..
	„ spp.	..	×	×	..	..	..	..	..	..	1	a.b. ..	..	..	..	×	..	..
	Sub-Kingdom MOLLUSCA. Class Pelecypoda. Order Prionodesmacea.																	
	Arca sp.	..	×	..	..	..	..	..	..	..	..	a. ..	..	..	..	..	..	..
W	**Alectryonia (Ostrea) Marshii** (Sowerby)	×	×	×	×	×	×	×	..	×	..	a.b.c.o.T.	×	×	..	..	..	..
	„ „ c.f.Marshii (Sowerby)	..	×	×	..	..	..	..	..	..	..	.. ..	..	..	×	..	..	..
	Avicula æqualis (Moore)	..	×	..	..	..	..	..	..	..	..	(c.) ..	×	..	..	×	..	..
	„ (Maccoyella) Barklyi (Moore)	..	..	..	..	..	..	..	..	..	1	B.(c.) ..	..	..	..	×	×	..
W	„ *echinata* (Sowerby)	..	×	×	..	..	..	..	..	..	..	b.c.o. ..	..	..	..	..	..	..
W	„ *inæquivalvis* (Sowerby) ..	..	×	..	..	..	..	..	..	..	1	b.c.o. ..	..	..	..	..	..	..
W	„ *Munsteri* (Bronn.)	..	×	..	..	..	..	..	..	..	..	a.b.c.o.	..	..	..	..	..	..
	„ spp.	..	×	..	..	..	..	..	..	..	..	a. ..	..	..	..	..	..	..
	Ctenostreon (Lima) pectiniformis (Schl.)	..	..	×	..	..	..	×	..	×	2	r.Q.T. ..	×	×	×	×	..	..
	[illegible]	..	..	..	..	..	..	..	..	..	..	B.c.o. ..	..	..	..	..	..	..
	[illegible]	..	..	..	..	..	..	..	..	..	..	T. ..	×	..	..	×	..	..

	„ *c.f.* **semistriata** (Moore)	..	..	×	×	×	×	×	×	..	..	×	2	B.c.o.q.r.T	×	×	×	×	..	..
	„ **tibraddonensis** (Eth. fil.)	..	..	..	..	×	..	×	..	..	..	×	..	T.	×	×	..	..	..	..
	„ **spp.**	..	×	×	×	..	×	×	..	..	×	1	a.b.T.	×	..	..	×	..	..
	Gryphæa spp.	..	..	×	×	..	×	..	..	..	..	2	r.	×	..	×	..	..	..
	Hinnites sp.	..	..	×	..	..	..	..	..	..	..	..	a.	..	..	..	..	..	..
	Lima Gordonii (Moore)	..	..	..	..	..	..	..	..	..	..	1	B.	..	..	..	..	×	..
W	„ proboscidea (Sowerby)	..	×	×	..	..	..	..	..	..	..	1	a.b.c.o.	..	..	..	×	..	..
W	„ punctata (Sowerby)	..	×	..	..	..	..	..	..	..	..	1	b.c.o.	..	..	..	×	..	..
	„ *spp.*	..	..	×	×	..	..	..	..	..	×	2	a.b.r.	..	..	..	..	..	..
	Modiola Maitlandi (Eth. fil.)	..	..	..	..	×	×	×	..	..	×	..	T.	×	×	..	..	..	..
	Mytilus c.f. gygerensis (D' Orb.)	..	..	..	..	..	..	..	..	..	..	2	a.r.	..	..	..	..	..	..
	„ *sp.*	..	..	×	..	..	..	..	..	..	..	..	a.	..	..	..	..	..	..
	Nucula sp.	..	..	×	..	..	..	..	..	..	..	..	a.	..	..	..	..	..	..
	Ostrea tholiformis (Eth. fil.)	..	..	..	..	×	×	×	×	×	×	..	T.	×	×	..	..	..	..
	„ *c.f.* **tholiformis** (Eth. fil.)	..	..	..	..	..	×	..	..	×	×	..	..	×	..	..	..	..	..
	„ **spp.**	..	..	..	×	×	×	×	..	..	×	..	b.T.	×	..	..	..	..	..
	„ **sp.** (very small)	..	..	×	..	..	..	..	..	..	×	..	a.	×	..	..	..	..	..
W	Pecten calvus (Goldf.)	..	×	×	..	..	..	..	..	..	..	1	b.c.o.	..	..	..	×	..	..
W	„ **cinctus** (Sowerby)	..	×	×	×	×	×	×	×	×	×	1	b.c.o.q.T.	×	×	×	×	..	..
	„ *c.f.* **frontalis** (Dum.)	..	..	..	×	..	×	..	..	..	..	..	r.	×	..	..	..	..	..
	„ **Greenoughiensis** (Moore)	..	..	..	×	..	..	..	..	..	×	..	B.c.o.	×	..	..	..	..	..
	„ **valoniensis** (Defr.)	..	..	..	..	..	..	..	..	..	..	3	..	×	..	..	..	..	..
	„ *c.f. vesicularis*	..	..	×	..	..	..	..	..	..	..	..	a.	..	..	..	..	..	..
	„ **spp.**	..	..	×	..	×	×	×	..	..	..	..	a.T.	..	×	×	..	..	×
	„ **sp.** (*or* **Ctenostreon sp.**)	..	..	..	..	×	..	..	..	..	..	..	..	..	×	..	..	..	..
	Perna sp. (*or* **Inoceramus sp.**)	..	..	..	..	×	..	..	..	..	..	..	..	..	×	..	..	..	..
W	*Plicatula sp.*	..	..	×	..	..	..	..	..	..	..	1	b.	..	..	..	..	..	..
W	**Radula (Lima) duplicata** (Sowerby)	..	..	×	..	×	..	×	..	×	×	1	b.c.T.	..	×	..	..	×	..	..
	„ „ *sp.*	..	..	×	..	..	..	..	..	..	×	..	a.	..	..	..	..	..	..	..
W	**Trigonia Moorei** (Lycett)	..	..	×	×	×	×	×	×	×	×	3	B.c.o.q.r.T.	×	×	×	×	×	..
	„ *costata* (Clarke) (? *Moorei*) (Lyc)	..	..	×	..	..	..	..	..	..	..	..	a.	..	..	..	..	..	..
	„ sp.	..	..	×	..	..	..	..	..	..	..	..	a.	..	..	..	..	..	×

	Genus and Species.	Locality.										Reference.	Exhibited.					
	Order Anomalodesmacea.	Shark Bay.	Moresby Range.	Greenough R.	Tibradden.	Moonyoonooka.	Sandspring.	Woolanooka.	Snake Farm.	Mount Hill.	Doubtful Locs.		Geol. Soc. Lond. Museum.	Australian Museum.	Victorian Museum.	Bath Museum.	British Museum.	Geol. Soc. Lond. Museum.
W	Gresslya donaciformis (Phill.) ..	×	..	×	..	..	..	..	..	..	1	b.c.o. ..	..	..	..	×	..	..
	,, *sp.*	..	..	..	..	..	..	..	..	..	2	b.r. ..	..	..	..	..	..	..
	,, (?) sp.	..	..	..	..	..	..	..	..	..	1	.. ..	..	..	..	×	..	..
	Homomya (?) sp,.	..	..	..	..	..	..	..	..	..	1	b.(c.) ..	..	..	..	×	..	..
W	**Myacites liassianus** (Quenst.)	×	..	..	..	..	..	..	..	..	1, 2	b.c.o. ..	×	..	..	×	..	..
W	,, **Sanfordii** (Moore)	..	..	×	..	×	..	..	..	×	1, 2	B.c.o.r.	×	×	..	×	..	..
	,, spp.	×	×	×	..	..	..	..	..	..	..	a.b. ..	..	..	..	×	..	..
W	**Pholadomya ovulum** (Agassiz) ..	×	..	×	..	..	..	..	..	..	1	b.c.o. ..	×	..	..	..	..	..
	,, *sp.*	..	×	..	..	..	..	..	..	..	..	a.b. ..	..	..	..	..	..	..
	Pleuromya sp. (?)	..	..	×	..	×	..	..	..	..	2	r. ..	×	..	..	..	..	..
	Order Teleodesmacea.																	
W	*Astarte apicalis* (Moore)	..	..	×	..	..	..	..	..	..	..	B.c.o. ..	..	..	..	..	..	..
W	,, **Cliftoni** (Moore)	×	..	×	×	×	..	×	..	×	2	B.c.o.q.r. T.	×	×	×	..	..	..
		×								×	2	a.b. ..	×	..	..	×	..	..

W	*Cardium sp.*	..	×	..	..	..	..	..	..	..	..	a.b.o.	..	..	..	..	..	..	..
W	Cypricardia sp.	×	..	..	..	..	..	..	..	..	..	b.o.	..	..	..	..	×	..	..
W	Isocardia sp.	×	..	..	..	..	..	..	..	..	..	b.o.	..	..	..	..	×	..	..
	Lucina sp. (? *Pseudavicula*, Eth. fil.)	..	×	..	..	..	..	..	..	..	..	a.	..	..	..	..	..	..	..
	Opis sp.	..	×	..	..	..	..	..	..	..	..	a.	..	..	..	..	..	..	..
	Panopæa (Glycimeris) rugosa (Moore)	..	..	..	..	..	..	..	..	..	2	..	..	×	..	..	..	..	..
	„ **sp. nov.**	..	..	..	..	..	..	..	..	..	2	..	..	×	..	..	..	..	..
	„ **sp.**	..	×	..	..	..	..	..	..	..	3	..	..	×	..	..	..	..	..
W	Tancredia plana (?) (Moore)	..	×	×	..	×	..	..	..	..	..	b.(c.)o.	..	..	×	..	..	..	..
W	Teredo (Pholas) Australis (Moore)	×	×	..	..	..	..	..	..	..	1	a.B.c.o.	..	..	..	..	×	..	..
W	*Unicardium sp.*	..	×	..	..	..	..	..	..	..	..	b.o.	..	..	..	..	..	..	..
	„ (?) sp.	..	×	..	..	..	..	..	..	..	..	*b.*	..	..	..	..	..	..	..
	Class Scaphopoda. Family Dentaliidæ.																		
	Dentalium sp.	..	×	..	..	..	..	..	..	..	..	a.	..	..	..	..	..	..	..
	Class Gastropoda. Order Aspidobranchia. Sub-Order Rhipidoglossa.																		
W	*Amberleya sp.*	..	×	..	..	..	..	..	..	..	..	b.o.	..	..	..	..	..	..	..
W	Phasianella sp.	×	..	..	..	..	..	..	..	..	1	b.o.	..	..	..	..	×	..	..
	Pleurotomaria Greenoughiensis (Eth. fil.)	..	..	..	..	..	×	..	..	..	..	T.	..	×	..	..	..	..	..
	„ **sp.**	..	..	..	×	..	..	..	..	..	..	..	..	×	..	..	..	..	..
W	*Trochus sp.*	..	×	..	..	..	..	..	..	..	..	b.o.	..	..	..	..	..	..	..
	Turbo Australis (Moore)	×	..	×	..	..	..	..	..	..	..	B.c.o.	..	..	..	..	×	..	..
W	„ *lævigatus* (Sowerby)	..	×	×	..	..	..	..	..	..	..	b.c.o.	..	..	..	..	..	..	..
	„ *sp.*	..	×	..	..	..	..	..	..	..	..	a.b.	..	..	..	..	..	..	..

	Genus and Species.	Locality.										Reference.	Exhibited.					
	Order Ctenobranchiata. Sub-Order Platypoda.	Shark Bay.	Moresby Range.	Greenough R.	Tibraddon.	Mooryoonooka.	Sandspring.	Woolanooka.	Snake Farm.	Mount Hill.	Doubtful Locs.		Geol. Surv. Museum.	Australian Museum	Victorian Museum.	Bath Museum.	British Museum.	Geol. Soc. Lond. Museum.
W	*Cerithium Greenoughiensis* (Moore) ..	×	..	×	..	..	..	..	..	..	..	B.c.o. ..	..	..	..	..	..	..
	.. *sp.*	..	×	..	..	..	..	..	..	..	..	b. ..	..	..	..	..	..	..
	Chemnitzia sp.	..	×	..	..	..	..	..	..	..	..	a. ..	..	..	..	..	..	..
W	*Eulima* (?) *sp.*	..	×	..	..	..	..	..	..	..	..	b.o. ..	..	..	..	..	..	..
	Nerinæa sp.	..	×	..	..	..	..	..	..	..	..	a. ..	..	..	..	..	..	..
W	Rissoina Australis (Moore)	×	..	×	..	..	..	..	..	..	..	B.c.o. ..	..	..	..	×	..	..
	Order Opisthobranchia. Sub-Order Tectibranchiata.																	
	Actæon depressus (Moore)	×	..	..	..	..	..	..	..	..	..	B. ..	..	..	..	×	..	..
	Class Cephalopoda. Sub-Branch Tetrabranchiata. Order Nautiloidea. Sub-Order Orthochoanites.																	
W	**Nautilus perornatus** (Crick) (1) ..	×	×	×	×	×	..	..	×	×	2	b.c.L.o.r.t.	×	×	..	..	×	..
	.. *sinuatus* (Sowerby) (?) ..	..	×	..	..	..	..	..	..	..	1	a.c.o. ..	..	..	..	..	..	..
	.. *spp.*	×	×	..	..	..	..	..	..	..	..	a. ..	..	..	..	×	×	×

	Order Ammonoidea.																	
	Ammonites lautus	..	..	×	..	..	..	..	..	..	..	.. ..	..	..	..	..	..	×
W	„ Walcottii (Sowerby) ..	×	..	×	..	..	..	..	..	..	..	b.c.o. ..	..	..	..	×	..	..
W	„ **(Dorsetensia) Clarkei** (Crick) (2)	×	×	×	×	×	..	×	×	×	2	a.B.c.L.O., r.T.	×	×	×	..	×	..
	„ **(Dorsetensia) sp.** ..	..	..	..	..	..	..	..	×	..	..	.. ..	×	..	..	..	..	..
W	„ (Dumortieria) Moorei (Lycett)	×	×	×	..	..	..	..	..	..	..	a.B.c.l.o.	..	..	..	×	..	..
	„ (Macrocephalites) macrocephalus (3) (Schlot)	×	×	×	×	..	..	..	..	..	..	B.c. ..	..	..	..	×	..	..
	„ (Macrocephalites) sp. ..	..	..	×	..	..	..	..	..	..	..	.. ..	..	..	..	×	..	..
	„ **(Perisphinctes) Championensis** (Crick)	..	..	×	×	×	..	..	..	×	2	L.o.Q.r.t.	×	..	×	..	×	..
	„ (Perisphinctes) robiginosus (Crick)	..	..	..	..	..	..	..	..	..	2	L.o.r. ..	..	..	..	..	×	..
W	„ **(Sphæroceras) semiornatus** (4) (Crick)	..	..	..	×	..	..	..	..	..	2	B.c.L.o.r. T.	×	..	..	×	×	..
	„ (Sphæroceras) (?) Woodwardi (Crick)	..	..	..	..	..	..	..	..	..	2	L.o.r. ..	..	..	..	..	×	..
	„ (Stephanoceras) Australis (Crick)	..	×	×	..	×	..	..	..	×	2	L.o.q.r.	..	×	×	×	×	..
	„ (Normannites) Australis (Crick) (*fide* Chapman)																	
	„ (Normannites) sp. ..	×	..	..	..	..	..	..	..	..	2	L. ..	..	..	..	..	×	..
	„ spp.	×	×	..	×	×	..	×	..	×	..	b. ..	×	..	..	×	..	..
	Sub-Class Dibranchiata. Sub-Order Belemnoidea.																	
W	**Belemnites canaliculatus** (Schl.) ..	×	×	×	..	..	..	×	..	×	..	a.B.c.o.	×	..	..	×	..	..
	„ **c.f. canaliculatus** (Schl.) ..	..	..	×	..	..	..	..	..	×	..	a. ..	×	..	×	..	..	..
(?)	„ **Canhami** (Tate) ..	..	..	..	..	..	..	..	..	..	2	.. ..	×	..	..	..	..	..
	„ **sp.**	..	..	×	×	×	×	..	×	×	2, 3	a.L.o.r.	×	×	..	..	×	..

	Genus and Species.	Locality.										Reference.	Exhibited.					
	Sub-Kingdom ARTHROPODA. Class Crustacea. Sub-Class Eucrustacea. Super-Order Ostracoda.	Shark Bay.	Moresby Range.	Greenough R.	Tibraddon.	Moonyoonooka.	Sandspring.	Woolanooka.	Snake Farm.	Mount Hill.	Doubtful Locs.		Geol. Surv. Museum.	Australian Museum	Victorian Museum.	Bath Museum.	British Museum.	Geol. Soc. Lond. Museum.
	Cythere corrosa var. grossepunctata (Chapm.)	..	..	×	..	..	..	..	..	..	..	Q. ..	..	..	×	..	..	..
	„ drupacea var. fortior (Chapm.)	..	..	×	..	..	..	..	..	..	..	Q. ..	..	..	×	..	..	..
	„ lobatula (Chapm.)	..	..	×	..	..	..	..	..	..	..	Q. ..	..	..	×	..	..	..
	Cytheropteron australiense (Chapm.)	..	..	×	..	..	..	..	..	..	..	Q. ..	..	..	×	..	..	..
	Loxoconcha elongata (Chapm.) ..	..	..	×	..	..	..	..	..	..	..	Q. ..	..	..	×	..	..	..
	„ jurassica (Chapm.) ..	..	..	×	..	..	..	..	..	..	..	Q. ..	..	..	×	..	..	..
	Paradoxorhyncha foveolata (Chapm.)	..	..	×	..	..	..	..	..	..	..	Q. ..	..	..	×	..	..	..
W	*Ostracoda—Species of*	..	..	..	..	..	..	..	..	..	1	b. ..	..	..	..	..	..	..

VI.—Western Australian Fossil Plants,

BY

LUDWIG GLAUERT, F.G.S.,

Field Geologist.

As explained in the general introduction the fossil flora of the State is very scanty, still it has been the cause of a good deal of discussion from time to time, as may be gathered from the Introduction and Historical Sketch in the Glossopteris Flora (1) by Mr. E. A. Newell Arber, of Cambridge University, and from several of the Bulletins issued by this Department. (2).

The Collie plant-remains were originally considered to be of Mesozoic Age, as explained by Mr. H. P. Woodward, in the Annual General Report for the year 1890, of the Government Geologist (page 40). A little later the late R. Etheridge, F.R.S., determined them as Permo-Carboniferous, basing his opinion on the specimens submitted to him for examination. In 1897, Mr. E. F. Pittman, the Government Geologist of New South Wales, classed them as Mesozoic in consequence of "Mr. R. Etheridge's (junr.), doubtful recognition of *Sagenopteris*." On the other hand, in 1898, Sir Frederick McCoy reported the determination with certainty of *Glossopteris Browniana* (Brong), and stated that the beds were of "the exact geological age of the great Coalfields of Newcastle in New South Wales." Dr. Jack, during his investigation, as Royal Commissioner, of the Collie Coal Industry, in 1904, came to the conclusion that the beds were of much later date, writing "I am at present inclined to believe that 'the Collie Coalfield will turn out to be possibly of Cretaceous Age. . . .'" (3.) In the following year, Mr. F. Chapman, of Melbourne, after examining some specimens in the Collection of the National Museum, Melbourne, identified five species of *Glossopteris*, as well as the following Foraminifera whose range in time is as under :—

Name.	Range in Time.
Endothyra, sp.	Carboniferous Limestone
Valvulina plicata (Brady) ..	L and U. Carboniferous
Bulimina (?) *sp.*	Permo-Carbonif. of N.S.W., Triassic to Recent
Truncatulina Haidingeri (D'Orb)	Permo.-Carboniferous
Pulvinulina c.f. exigua (Brady)	(Genus) Lower Lias to Recent.

(1.) Catalogue of the Fossil Plants of the Glossopteris Flora in the Department of Geology, British Museum (Natural History), London 1905.
(2.) Bulletin G.S., W.A., 26, p. 58 *et. seq.*, Bull. 27, articles 1 and 2, 1907.
(3.) Report of the Royal Commission on the Collie Coal Field, 15 p. 7—1905.

Although the two doubtful forms may belong to more recent beds, the species determined with certainty are typically Carboniferous, the whole series "point in a general way to the Palæozoic (Permo-Carboniferous) Age of the series in which they were found." Since that time, no conflicting evidence has come to hand, so that in spite of the peculiar lithological character of the beds there seems little if any doubt about the age of the Collie Coal Seams, and their associated fossils. (1).

Though the known Palæozoic flora of the State is scanty, that obtained up to the present from the Mesozoic beds is much more so. Before the specimens described by Mr. Newell Arber in this Bulletin were found, the discoveries were limited to badly-preserved fossil wood, similar to the pieces referred to by Mr. Arber on page 27, so that the determination of even the one species, *Otozamites Feistmanteli* (Zigno), is a great advancement, one which suggests that the locality near Mingenew may yield a good harvest at some future time when it is possible to make a prolonged and systematic search in the beds, whence these few plants were obtained by Mr. W. D. Campbell, in 1908.

References.—The plan adopted in the list of the fossil fauna is continued.

(1) *Glossopteris* is a genus of ferns which is looked upon as being not younger than Triassic or Rhœtic, E. A. Newell Arber, *loc. cit.*

WESTERN AUSTRALIAN FOSSIL PLANTS.

(*a.*) PALÆOZOIC.

The following plants are recorded from Carboniferous and Permo-Carboniferous Strata :—

Genus and Species.	Locality.	Reference.	Exhibited.		
			Geol. Surv. Museum.	Australian Museum.	Victorian. Museum.
Calamites sp.	Kimberley	e.			
Chondrites (?) sp.	Minilya R.	n.P.u.	×		
Cyperites (?) sp.	Kimberley	I.	×		
Glossopteris Browniana (Brong.)	Gascoyne R. and Collie Coalfield	n.r.S.	×		×
„ **angustifolia** (Brong.)	Collie Coalfield	n.r.S.	×		×
„ communis (Feistm.) *	Do.	n.r.S.			×
„ **gangamopteroides** (Feistm.)	Do.	n.r.S.	×		×
„ Indica (Brong.) *	Do.	n.r.S.			×
„ **spp. ind.**	Do.	n.r.s.	×	×	
„ **(Vertebraria) sp.**	Collie Coalfield and Bulls Brook	n.r.S.	×		×
Lepidodendron sp.	Kimberley	e.i.r.	×		
„ **(Knorria condition) sp.**	Do.	e.i.	×		
„ (*Sagenaria*) *sp.*	Do.	e.			
Lepidophyllum (?) *sp.*	Do.	e.			
Lepidostrobus sp.	Do.	e.i.			
Rhizomopteris (?) sp.	Collie Coalfield	S.			×
Sigillaria sp.	Kimberley	e.			
Stigmaria sp.	Do.	e.r.			
Noeggerathia (?) sp.	Collie Coalfield	r.s.	×		

* Some authorities consider these two species to be identical. *Vide* Bulletin 27, pp. 12 and 13.

(*b.*) MESOZOIC.

The following plants are recorded from Jurassic Strata:—

Genus and Species.	Locality.	Reference.	Exhibited.		
			Geol. Surv. Museum.		
c.f. **Araucaria peregrina** (Kurr.)	3 m. South of Mingenew ..	t.	×	..	..
c.f. **Cunninghamites Australis** (Ten. Woods) ..	Do.	t.	×	..	..
c.f. Pagiophyllum sp.	Do.	t.	×	..	..
Otozamites Feistmanteli (Zigno)	Do.	t.u. ..	×	..	..
„ **sp.**	Mount Hill	u. ..	×	..	..
Fern fronds	3m. South of Mingenew ..	t.u. ..	×	..	..
Seed Vessels	Do.	t.u. ..	×	..	..
c.f. Williamsonia pecten (Phill.) *	Point Torment near Derby ..	.. ..	×	..	..

* This is the first indication of the presence of Mesozoic strata in the Kimberley Division of the State.

VII.—New Fossils from the Napier Range, Kimberley,

BY

LUDWIG GLAUERT, F.G.S.,

Field Geologist.

During Mr. H. P. Woodward's visit to the Kimberley area in the year 1906, with a view of reporting on the Narlarla Hills, he had an opportunity of collecting a few fossils which have proved to be of great interest and importance, on account of the light which they shed upon the exact age of large tracts of country, and the bearing they have on the Geological Maps of the district, as interpreted by the late E. T. Hardman and Dr. R. Logan Jack. These two authorities considered the Napier Range to consist of Carboniferous beds only, with a bed of conglomerate at the base of the series. This "basement conglomerate" mainly consists of fragments of the older igneous and metamorphic rocks and appear to greatly resemble the "Basement Conglomerate" so often found under the Carboniferous Limestone, etc., in the British Isles, and considered to be of Carboniferous age.

From Mr. Woodward's results, however, it is evident that the conglomerate is truly Devonian, and that most likely in Western Australia it is the basal bed of the Devonian strata, and not of the Carboniferous.

Perhaps at this juncture it is advisable to quote Mr. Woodward's account of the beds as exposed in the Barker Gorge—a gorge cut through the Range by the Barker River in its course from the King Leopold Ranges to the Meda River and the Sea. Mr. Woodward writes as follows:—

> "The Napier Range consists of a series of crystalline limestone beds which strike in a north-westerly and south-easterly direction and dip at an angle which varies from 12 to 23 degrees to the south-westward. These beds present the usual character of the Palæozoic limestone of this State, viz., they consist of a series of thick solid crystalline beds of a grey colour interbedded with soft calcareous bands of a more argillaceous character, whilst the basement beds consist of calcareous breccia and conglomerate, the enclosures in which consist of masses, fragments, boulders or pebbles of schist, granite, and quartz derived directly from the crystalline schists, granites, and greenstones upon which they rest. This range, which rises to an elevation in places to 400 feet above the adjoining plain from which it rises abruptly, is

fairly riddled with caverns and has been intersected at one or two points by watercourses which have cut deep gorges through it, varying from 2 to 4 miles in length.

"In the gorge formed by the Barker River (142° 43′ E. long., 170° 16′ S. lat.), one of the tributaries of the Meda River, a fine section of these limestones is exposed dipping beneath the sandstones and shales which form the plain to the south-westward and have provisionally been classed as Upper Carboniferous. *

"Some little time was spent in searching for fossils in the softer beds above-mentioned, but without success. Just before my departure, however, some red coloured limestones were discovered in a small branch gully upon the south side of the Gorge and near the base of the series, which proved to be full of organic remains. Owing to their hardness, however, forms could only be identified upon the weathered surfaces, and since my party had already started I was only able to carry away as many as my pockets would hold."

These specimens were in due course forwarded to the British Museum, London, for identification by the officers on the staff of that Institution. On the 16th of March, 1908, Dr. Henry Woodward, F.R.S., the late Keeper of the Geological Department, returned the fossils, writing as follows in his covering letter of the same date :—

"I now return the specimens, with such information as I have been able to collect concerning them."

[**6923.**] (F327) 1.—The fish bone with "berry"-like sculpturing upon its surface must be referred to a large Devonian fish (new to science) allied to *Coccosteus*, but the specimen is not sufficient to determine accurately its relation to the skeleton.

[**6928.**] (F334) 2.—Tail of a Trilobite genus—*Proetus*, a new species.

[**6928A.**] (F335) 3.—Head of a Trilobite (part of same specimen) (?) and counterpart of tail.

[**6926.**] (F331) 4.—Crinoid stem (?) also remains of a gasteropod shell seen in section, *Loxonema sp.* (?)

[**6929.**] (F336) 5.—Imperfect specimen of a gasteropod, in white spar. *Euomphalus sp.* (?).

[**6925.**] (F329) 7.—A Rhynchonella, near to *R.* (*Uncinulus*) *Timorensis* Beyr. and *Pachypora sp.* on same block.

[**6924.**] (F328) 10.—A coral, *Phillipsastræa sp.*

[**6925A.**] (F330) 11.—*Pachypora sp.* (*see* [**6925**], above).

[**6927A.**] (F333) 13.—Two crinoidal stems (not determined).

[**6927.**] (F332) 14.—A. Crinoidal arm } on same block.
B. *Goniatites sp.* }

* *See* Hardman's 1884 Report, pages 9 and 20.

"I am sorry to offer you such poor determinations, but (although the rock is full of fragments) the specimens are very imperfect and obscure, the small Brachiopod, the pygidium (tail) of the Trilobite and the coral, *Phillipsastræa*, being the only clearly preserved ones. The facies of the fauna, especially the fish plate *Coccosteus* (*c.f.*), is undoubtedly Devonian."

On an enclosed slip Dr. Woodward writes:

"The matrix and the fossils agree closely with the Devonian of Adorf in Waldeck, Germany, *see* E. Halzapfel, 'Die Goniatiten-Kalke von Adorf in Waldeck,' Palæontographica Bd. XXVIII., Lief. VI., Jan., 1882, pp. 225–262, pls. XLIV., (I.), XLIX., (VI)."

Two other enclosures are of interest, being letters from Dr. A. Smith Woodward concerning the fish remains. On the 25th of March, 1907, this authority writes:

"The Western Australian Fossil looks remarkably like a piece of a large Devonian Coccostean, hitherto unknown in the Australian Region, but it is not good enough for exact determination. I will try a fragment under the microscope to discover whether the tissue is true bone."

Again, on the 25th of the following month the same gentleman gives the following information:—

"I have compared this bone again and am sorry it is too imperfect to determine from its shape its true nature. The texture and the ornament agree more closely with those of Coccostean fishes than with any other. I therefore think the new fossil belongs to one of the armoured Devonian fishes such as have not hitherto been satisfactorily determined in Australia."

It will be thus seen that competent opinion is agreed upon the age of these red limestones being Devonian, in fact, not the slightest suspicion is expressed by Dr. Woodward in his letter as nothing could be more definite than his assertion.

If we regard such genus represented separately we notice that the facies is as follows (1):—

Genus.	Distribution in Time.
1. *Pachypora sp.*	Silurian to Devonian.
2. *Phillipsastræa sp.* ..	Devonian and Carboniferous.
3. *Rhynchonella* (*Uncinulus*)	Devonian chiefly.
4. *Euomphalus sp.* ..	Silur. Dev. Carbonif., Perm., Trias.
5. *Loxonema sp.*	Silur. Dev. Carbonif. Perm. Trias.
6. *Goniatites* (*Glyphioceras*)	Devonian and Carboniferous.
7. *c.f. Coccosteus* ..	(Coccostean fish) Devonian only.

On analysis it is apparent that the facies is most decidedly Devonian. We have one form, the Coccostean fish, which is absolutely confined to that age; one genus, *Pachypora*, which becomes extinct before the Carboniferous, a coral, *Phillipsastræa*, which,

(1.) *Fide* Zittel.

though present in Carboniferous rocks is most plentiful in the Devonian, and a cephalopod, *Goniatites* (*Glyphioceras*) that is equally abundant in Devonian and Carboniferous times. *Euomphalus* and *Loxonema* though at their prime in the Carboniferous are plentiful in the Upper marine Devonian. The only possible exception is the *Rhychonella* (*Uncinulus*) *c.f. Timorensis*, but this loses its weight when we remember that the specimen is *not identical* with the Timor form but that it bears a *great resemblance* to that shell. and bear in mind that some of the Brachiopod shells living to-day in the seas off the coast of Australia, Great Britain, etc., can scarcely be distinguished from their ancestors found in some of the oldest fossiliferous beds of Europe and America.

The existence of the true Devonian beds in Western Australia was formerly more or less a matter of conjecture, as the true Devonian fossils were few and very far between, so that this confirmatory evidence from the Napier Range is very opportune, and reflects credit upon the authorities who determined the presence of Devonian beds when undertaking the pioneer geological work in this vast State twenty years ago.

VIII.—The Geological Age and Organic Remains of the Gingin "Chalk,"

BY

LUDWIG GLAUERT, F.G.S.,

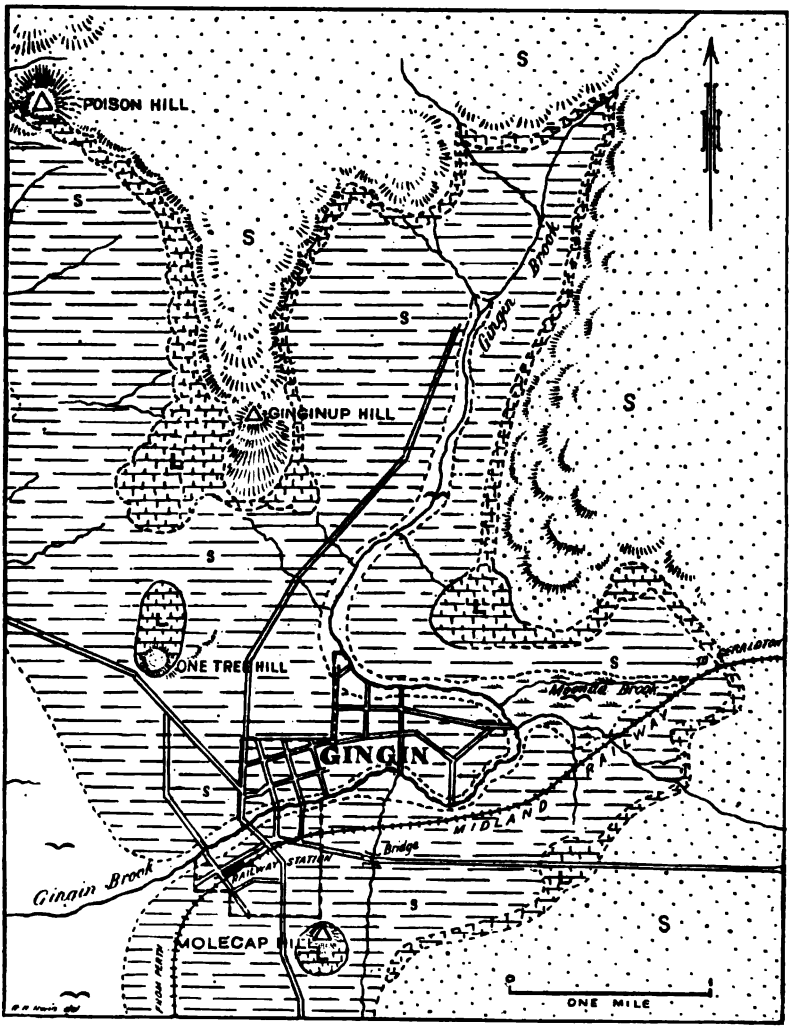
Field Geologist.

The name "Gingin Chalk" has been given to a thin bed of white chalky limestone that is exposed in various places in the vicinity of Gingin, * the best known being the summit of One Tree Hill, where the stone has been quarried for the manufacture of lime and cement.

The exposure shows a white chalk without flints, about 15 feet in thickness, which passes downwards into a greenish glauconitic marl and below that into a clayey rock. The character of the beds is not at all constant, as the most easterly patches consist mainly of clay (block 127, South of Moonda Brook), the amount of limestone increasing to the westwards. In all the localities the presence of the beds can be determined by the exceedingly rich black clayey soil due to the weathering and disintegration of the rock, a soil which bears rich crops of grass or cereals, remarkable even in that good Agricultural District. The knolls on the flanks of Ginginup, or Sunday Hill, and on both banks of the Moonda Brook, as well as the outliers forming the crowns of One Tree Hill and Molecap Hill, are recognisable in this way, but where the beds are situated in an escarpment, or hill side, the debris from the overlying ferruginous sandstone beds tends to obliterate this feature, thus rendering the tracing of the beds a matter of some difficulty. The largest exposure is on the western and southern sides of Ginginup, or Sunday Hill, and is several square miles in extent. As is usually the case in this district no good exposures or escarpments are visible, so that it is difficult to ascertain the dip and strike of the beds. Several small masses of limestone, which seems to be *in situ*, were noticed and, though the dip varied both in direction and amount, the general trend of the strata seemed to be horizontal. The rich black soil studded with fragments of limestone of all sizes was very conspicuous in the ploughed land and in the banks of the small gullies.

* *Vide* Lands Department 80 chain Lithographs 28 and 31.

FIG. 4.


POISON HILL
GINGINUP HILL
ONE TREE HILL
GINGIN
MOLECAP HILL
Gingin Brook
Mogumber Brook
MIDLAND RAILWAY
STATION
Bridge
ONE MILE
S
L
EXPLANATION
ALLUVIUM
FERRUGINOUS SANDSTONE
GINGIN "CHALK" & CLAY
VARIEGATED CLAY (& Shale)
Boundaries obscured by drift sand and superficial deposits.

The One Tree Hill exposure is the best example, as the position is very prominent and is also conveniently situated. It has received attention from the industrial world, as for some years the " chalk " has been quarried and burnt for lime in the two draw-kilns close at hand. Although the quality seems to have been excellent, the time required for " slaking " was considered detrimental by builders and contractors, so that the industry had to be abandoned for the time being.

The quarry however, is of special interest, as it presents, we may say, the only clear section of the beds. Under a layer of soil and subsoil, averaging about 12 inches in thickness, there is a band of white, rather crumbly, limestone almost free from impurities and containing no fossils ; measuring about 18 inches. This is followed by a " chalk " which becomes richer in alumina and silica as it is followed downwards, till finally at about 15 feet below the purer limestone it resembles a greenish glauconitic clay.

The large Lamellibranchs are found in the upper portion of the main bed, and seem rare or entirely absent in the lower strata, where dwarfed Corals, Brachiopods, Lamellibranchs and Gastropods, as well as numerous Serpulæ and Echinoderm spines represent the remains of the animal life of the day, which appears to have been very adversely influenced by the muddy, if not turbid, water in which the creatures were compelled to pass their existence.

The fossils which were obtained during a visit (June, 1909), have not yet been subjected to careful examination owing to the lack of time, still, amongst the new records are Corals and Gastropods, as well as a species of Serpula very different from the involute form so plentifully represented in all the collections of Gingin fossils.

In this locality the beds have a slight northerly dip of eight or nine degrees.

The bow formed by the Gingin Brook before being joined by the Moonda, partly encloses another mass that has similar character and rivals the One Tree Hill outcrop in extent.

At the eastern edge of the patch on the Bindoon Road, two miles from Gingin Railway Station, an exposure in a gully shows the greenish-yellow glauconitic clay with two or three thin layers of limestone. Lastly, on the hillside east of Moonda, the clay is noticed in the channel of a gully without any trace of the limestone.

The exact relationship between the " chalk " and the overlying ferruginous sandstone and the underlying variegated clay or shale could not be definitely established as no section was to be seen, still, the general character of the beds in the district suggests the absence of any unconformity, although it must be noted that a bed of sandstone below the lime-kilns on One Tree Hill had an apparent dip of eight degrees south, which may be due to settling after the removal of the underlying clay by the rain, etc.

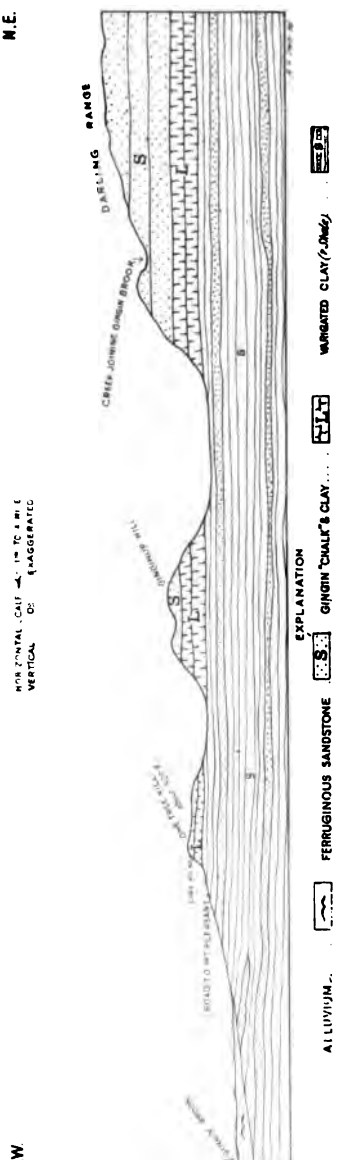


Fig. 5.

The following section shows the probable course and distribution of the various beds proceeding from the flats below Gingin through One Tree Hill to Ginginup and the Darling Range in a N.N.W. direction.

The presence of a bed of chalk in Western Australia has been known for over 50 years. Gregory's map of 1860 * shows two patches of "chalk and sandstones containing flints and Cretaceous fossils"; they are situated at Gin Gin and Yatheroo, and measure, roughly speaking, eight by five miles and six by three miles respectively. This map was exhibited at a meeting of the Geological Society to illustrate a paper by F. T. Gregory on the Geology of the Colony, and was subsequently printed.† In the paper Gregory states:

> "The Cretaceous (?) are the most extensively developed of the sedimentary rocks of Western Australia, and are almost exclusively silicious in character, *containing only a few beds of chalk* of very inferior quality." "They abound however, more in fossils than the Carboniferous do, and, with the exception of the recent coast limestones, more so than any other formation. Flints are rarely found in them." "The bed of the Greenough River is the best spot for procuring specimens, although a few are found in the chalk hills near Gin Gin (Echinoderm spines, etc.)"

* General outlines of the Geology of Western Australia, compiled by F. T. Gregory, F.R.G.S.—1860. Published in 1861 by John Arrowsmith of London.

† On the Geology of a part of Western Australia. Quart. Jour. Geol. Soc. (London), 1861, Vol. XVI. pp. 475–483.

These remarks are of interest, as they show that Gregory considered the Gingin Chalk to be Cretaceous in age, and very closely connected with the Jurassic Beds of the Greenough River. That these latter are thought to be Cretaceous is confirmed, firstly by his map (1), and secondly by the fossils which he presented to the Geological Society being classed by him as Cretaceous (?).

Mr. C. Moore examined these fossils and found them to consist

> " of a single cast of *Trigonia Moorei*, Lycett, and a very much worn *Pecten*, of uncertain species, both evidently of Oolitic age. They were accompanied by a *Ventriculites* in flint, a portion of a chalk Ammonite, and also by a considerable number of specimens of the age of the Carboniferous Limestone."

In the paper on " Australian Mesozoic Geology and Palæontology," (2) from which the above quotation is taken, Mr. Moore also refers to the " siliceous cast of a *Micraster* from the Chalk " in a set of fossils forwarded by Mr. Shenton.

Mr. H. Y. L. Brown in his general Report of 1873, writes as follows on page 13:—

> " The white chalky limestone of Gin Gin, Yatheroo, and Dandarragan, which outcrops from beneath the sandy soil of these localities in patches, most likely is also of Mesozoic age. As yet, owing to the surface accumulations of sand, etc., which hides it from view, no sections are to be seen which show whether it is over, or underlies the ferruginous rocks of the District."

A Geological Map of Western Australia * was issued to show the work done from August 1870, to June, 1872, by Mr. H. Y. L. Brown, who was the Government Geologist during that period. Upon this map the three patches of " white limestone " referred to above are shown to be approximately of equal area, measuring about seven miles by six miles.

In the year 1903, Mr. E. S. Simpson paid a short visit to the locality and examined some of the outcrops. In the quarry on One Tree Hill he obtained some fossils which were forwarded to Mr. R. Etheridge, Curator of the Australian Museum, for examination.

His conclusions upon these fragmentary and badly preserved specimens are given on page 38 of Bulletin No. 27 †, and are now quoted in full.

Fossils from Chalk Pit One Tree Hill, Gingin.

[**5551.**]—Chert ? semi-stalactitic.

[**5552.**]—*Ostrea*, allied to *O. vesicularis*, Lamk.
(F238)

(1.) In a section taken from this Map as shown as fig, 2, on page 477 of Vol. XVI. (1861) of the Quarterly Journal of the Geological Society, the Carboniferous beds of the Kennedy Range are classed as Cretaceous (?), the true relationship of the beds is shown by Mr. A. Gibb-Maitland the Government Geologist in fig. 6, page 15 of Bulletin No. 33—1909.

(2.) Quarterly Journal of the Geol. Soc. London, Volume XXVI., page 227, 1870.

(*) Printed by H. G. deGruchy, & Co. Melbourne—no date.

† Palæontological Contribution to the Geology of Western Australia, II.—Bulletin No. 27—Perth, 1907.

[5553.]—Crushed Brachiopod, possibly a *Magellanic*. (F239)

[5554.]—*Terebratulina* (?) This is quite distinct from any (F240) other described Australian Tertiary Brichiopod, and if examples can be obtained, showing the interior, is worthy of description.

[5555.] - *Serpula*, quite undescribed as an Australian form. It (F241) is allied to the European Tertiary Serpula. *S. Bognoriensis*. Specimens are retained for description.

[5556.]—Spines of two species of Echinids *Phyllacanthus*, (242) spines belonging to species of this genus have been found in the Tertiary beds of Willunga, S.A.

[5557.]—Portion of the shell of the Bivalve *Placunanomia*. (F243) Could a more or less perfect example be procured it would be worth description.

"The fossils from One Tree Hill Chalk Pit are certainly not older than Tertiary, but the evidence is of too limited a nature to enable me to suggest any horizon within that great formation, but I suspect the deposit must be well up in the series; for the sake of a name, and until more is known, call it Upper Tertiary. The condition of the fossil is not one that lends itself to accurate determination, but the *Terebratulina* (?) *Serpula* and *Placunanomia* certainly seem to be new, and if additional specimens of the first and last can be obtained the whole are worthy of description."

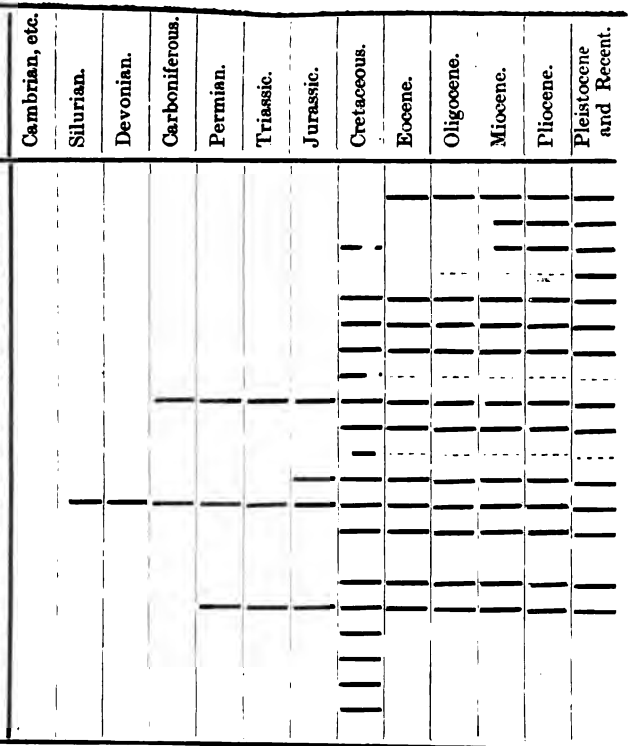
It will be noticed that Mr. Etheridge remarks upon the very unsatisfactory state of the few fossils submitted to him, and there is no doubt that if the asscciated fossils obtained from the same quarry at various times and presented to the Western Australian Museum had been sent to him with those of the Survey collection, he would have come to very different conclusions; that is to say, he would unhesitatingly have classed them as Cretaceous.

The Palæontological Contribution to which Mr. Etheridge's determinations form an introduction, is a list and description of Gingin Chalk Foraminifera. Thirty-seven species of these small organisms are described, eight of which are practically, if not entirely, confined to Cretaceous beds in the other parts of the globe. On the other hand only four species (one of them doubtful) are peculiar to the Upper Tertiaries, whilst 27 are known to have existed in Cretaceous times.

These facts struck Mr. Chapman of the National Museum, Melbourne, for in a letter to the Government Geologist under the date of February 22nd, 1908, he writes: "Mr. Howchin's list of Foraminifera from Gingin interests me very much, and *I cannot help concluding from the evidence of that group alone, that the deposit is decidedly Cretaceous.*"

In order to place the matter more clearly, and as an assistance for future reference, these Foraminifera are given in tabular form together with their distribution in Geological Time.

*	Foraminifera—Genus and Species.
R.	*Miliolina oblonga* (Montagu) .. ..
1	*Spiroloculina* (?) *grata* (Terq.) .. ..
C.	„ *asperula* (Kar.) .. ..
1	*Placopsilina vesicularis* (Brady) .. ..
S.	*Textularia trochus* (d'Orb.) .. ..
R.	„ *turris* (d'Orb.) .. ..
R.	„ *sagittula* (Defr.) .. ..
R.	„ *globulosa* (Ehr.) .. ..
C.	„ *gibbosa* (d'Orb.) .. ..
1	*Verneuilina spinulosa* (Reuss) .. ..
C.	„ *polystropha* (Reuss) .. ..
R.	*Lagena hispida* (Reuss) .. ..
R.	„ *globulosa* (W. & I.) .. ..
C.	*Nodosaria consobrina* var. *emaciata* (Reuss) .. ..
S.	„ *vertebralis* (Batsch) .. ..
S.	„ *soluta* (Reuss) .. ..
1	„ *obliqua* (Linné) .. ..
1	*Frondicularia intermittens* (Reuss) .. ..
S.	„ *chapmani* (Perner) .. ..
1	„ *gaultina* (Reuss) .. ..
S.	*Flabellina interpunctata* (v.d. Marck) .. .. ..



1 One specimen only. C. Common. R. Rare. S. Several.

	FORAMINIFERA—Genus and Species.	Cambrian, etc.	Silurian.	Devonian.	Carboniferous.	Permian.	Triassic.	Jurassic.	Cretaceous.	Eocene.	Oligocene.	Miocene.	Pliocene.	Pleistocene and Recent.
C.	*Marginulina costata* (Batsch)													
C.	*Cristellaria rotulata* (Lam.)													
C.	„ *cultrata* (Mont.)													
Sc.	„ *orbicularis* (d'Orb.)													
M.C.	„ *acutauricularis* (F. & M.)													
R.	„ *ovalis* (Reuss)													
V.C.	*Globigerina bulloides* (d'Orb.)													
S.	„ *cretacea* (d'Orb.)													
V.C.	„ *linnæana* (d'Orb.)													
Sc.	*Discorbina opercularis* (d'Orb.)													
R.	*Truncatulina lobatula* (W. & I.)													
Sc.	„ *variabilis* (d'Orb.)													
R.	*Rotalia Beccarii* (Linné)													
Sc.	„ *broeckhiana* (Kar.)													
1	„ *soldanii* (d'Orb.)													
1	*Nonionina asterizans* (F. & M.)													

C. Common. M.C. Moderately common. V.C. Very common. Sc. Scarce. 1 One specimen only. R. Rare. S. Several.

In the Geological Survey Museum there is an interesting suite of fossils which were presented to the Western Australian Museum in 1897 by Mr. W. R. Philbey ; though not in good condition, they are sufficiently well preserved to give an insight into the age of the Gingin chalk beds in which they were found. They comprise examples of various groups of animals Echinoderms, Worms. Brachiopods, Lamellibranchs, Cephalopods, and a Shark's tooth.*

Serpula sp. cf. *S.* (*V.*) *concava* (1) Sowerby [**10091**]. By far the most plentiful are splendidly preserved *Serpulæ*, animals which seem to have found congenial surroundings in that part of the Ocean where this bed of Chalk was forming. The numerous specimens plainly show that there was a certain amount of variation in the shape which the coiled tube assumed. One form may be described as discoid, involute, with a portion of straight tube ; almost flat on one side and concave on the other, the innermost whorl (s) often wanting ; being the chief point of attachment to the foreign object. (2) The form at the other extreme has one side of the involute tube more concave and the other convex, or obtusely conical. The surface of the tube shows the markings known as " lines of growth " but bears no other ornamentation ; longitudinal furrows or ridges which are to be seen on *S. Bognoriensis* (3) are entirely absent. A large umbilicus on the concave side, absent on the other (the side of attachment) owing to the manner in which the shell-matter has been deposited. Section of the tube circular both interiorly and exteriorly, the tube is thick in the older portions but thin at the natural opening. in this way differing from Sowerby's *S. tumida*. (4).

The average dimension (diameter) of the full grown individual is 16 m/m across the widest part of the involute portion, the largest I have seen, measuring 18½ m/m. The number of whorls is four or five.

I have compared the specimens with the figures and descriptions in the few works of reference to which I have access, and find that Sowerby's *V. concava* is the form most nearly approached by the Gingin shells. Sowerby describes his species, which is from the Greensand of Dilton near Westbury, England, as " discoid, involute, concave on one side, the last whorl but slightly attached." Below he states, " this is almost wholly involute with but a small portion of straight tube. the surface is nearly smooth and even, the involute part is concave on one side only, the other being flat.

---

* These fossils have been forwarded to Mr. R. Etheridge of the Australian Museum for detailed examination.

(1.) Sowerby's Min. Conch. (*Vermicularia cancava*), Volume I., page 125. pl. 57, figs. 1–5.

(2.) In the quarry on One Tree Hill, Gingin, I have seen specimens of the Serpula attached to fragments of shell, but as soon as they were handled they became disunited. The scars are generally seen on the flat or convex side of the involute tube.

(3.) Somerby's Min. Conch., Volume VI., page 194, pl. 596, figs. 1–3.

(4.) Sowerby's Min. Conch., Vol. I., page 125, pl. 596, fig. 4.

It seldom exceeds three-fourths of an inch in diameter, with about four turns."

Sowerby's *S.* (*Vermetus*) ***Bognoriensis*** to which Mr. Etheridge compares the Serpula, is described: * "Spiral portion conical, sub-discoid, concave beneath, tube obscurely five sided, with a furrow above and below; the produced part cylindrical, slightly curved. The tube is more angular, and the whorls more numerous than in *V. concava*, to which it nearly approaches, but when the surface is worn it appears cylindrical."

The Gingin specimen differs to some extent from both these specimens, but seems to bear closer relations to them than any other form with which I have been able to compare it, so that it is unnecessary to refer to any other species. There are obvious differences between the Gingin Serpula and *S.* (*V.*) *concava*, such as the habit of assuming an obtusely conical form, the state of attachment of the last whorl and the thickness of the whorls, but I have no doubt that the shells are closely related.

Among the specimens collected in June, 1909, I have noticed a small Serpula [**8922**] very like Sowerby's *Serpula fluctuata* (1) from the Chalk Marl.

Echinodermata.

This group is represented by numerous spines [**10092**] of varied size and pattern; the longest measures about 43 m/m, whilst the shortest would not exceed one-third of that length. In a general way they resemble the numerous muricated Cidarid spines plentiful in the white chalk and other Cretaceous beds of Europe. Mr. Etheridge refers the spines to species of *Phyllacanthus* in his short note upon some of the Gingin remains. (†) Numerous hexagonal plates, evidently portions of the test, were obtained in June last, and have been submitted to Mr. Etheridge for examination.

Brachiopoda.

The seven Brachiopoda belong to three genera, as far as can be judged from the external characters. One specimen is large but the others are small and delicate.

The large shell [**10095**] measures 40 by 27 m/m, and bears a striking resemblance to the *Terebratula biplicata* (2) Brocchi, figured by Davidson as a variation of the species. It is possible that this shell is not from Gingin, for the chalky material filling the shell seems harder than the usual Gingin rock, and the state of preservation of the shell is different.

Two small shells [**10094**] with fine radiating costæ and concentric lines of growth upon a shell showing a marked plication, are

* Loc. cit.
† Bulletin No. 27, page 38.
(1.) Min. Conch., Vol. VI., page 228, pl. 608, fig. 5.
(2.) Monogr. Brit. Fossil Brachiopoda., Vol. I., part 2, pl. VI., figs. 19–20.

identical with [5554] which Mr. Etheridge has determined as a (?) *Terebratulina*. (1)

Another group [10093] that has a smooth shell very finely punctate, but showing concentric lines of growth and possessing a slight plication, has been referred to by Mr. Etheridge as possibly a *Magellania*. (2)

Two somewhat larger shells showing no plication have been classed provisionally with the above, under number [10093]. The limited number of the specimens and absence of all knowledge of the interior of the shell makes further investigation impossible.

Pelecypoda (Lamellibranchiata.)

Inoceramus spp. etc.

After the *Serpulæ* the most commonly represented shells are undoubtedly those belonging to species of *Inoceramus*, etc. [10096].

Almost every rock in this collection of Gingin Fossils contains fragments of the shell of this striking genus so readily distinguished by the prismatic fibres of the thick outer layer of the shell. There are also more or less perfect internal casts, occasionally with fragments of the shell adhering to them.

The general outlines of the individuals and the structure and ornamentation of the shell are good indications of the genus to which these specimens have been referred, though the umbonal region and the hinge line are missing. There are some specimens, which in a general way, resemble the *I. pernoides* from the Queensland Cretaceous, others which remind one of Sowerby's *I. mytiloides*; McCoy's *I. Carsoni*; D'Orbigny's *I. problematicus* or Mr. Etheridge's *I. elongatus*, all of which are referred to by Mr. Etheridge in his Palæontology of Queensland. (3) Several specimens are like *I. constrictus* (Eth. fil.) (4) in form, but all are incomplete.

There are remains, mostly fragmentary, of other Pelecypods, but they are unsatisfactory for purposes of identification, as important portions of the shell are missing.

It seems that the following genera may be represented. *Pseudavicula*, *Ostrea*, *Gryphæa*, *Mytilus* and possibly *Glycimeris*, and others (5.)

See [10096], [10100] and [10103], under which numbers are included all the Pelecypods of the collection.

(1.) Bulletin No. 27, page 38.
(2.) Loc. cit.
(3.) Jack and Etheridge Geol. & Pal. of Queensland, page 463, *et seq.* and plates.
(4.) Queensland Geol. Survey Bulletin No. 13, page 24, plates II. and III.
(5.) A careful comparison of these specimens with the numerous Lamellibranchs of the Older Tertiary of Australia, figured and described by Prof. R. Tate in the Transactions of the Royal Society of South Australia, may have important bearing upon the age and relationship of the strata.

Cephalopoda.

In determining the age of Mesozoic beds, the presence of Ammonites is of great value ; it is therefore satisfactory to be able to state that two genera are present [**10101**], [**10102**]; one of which, *Crioceras*. (?) is undoubtedly Cretaceous. The other genus is represented by numerous examples, two more or less perfect casts of a large discoid Ammonite with somewhat inflated whorls.

[**10101.**] The specimens are in a poor state of preservation, with most of the characteristics either completely obliterated or rendered very indistinct. However, there are several points that can be distinguished. The whorls have an oval section, rendered lunate through their embracing the preceding ones, and are a little higher than wide, they show no signs of a keel and seem to bear a number of ribs which pass across the venter of the shell with a slight forward curve. There are no signs of tubercles, spines or any other secondary ornamentation. The greatest width of the whorl is at the highest point of the encroachment by the preceding one. The umbilicus is very indistinct, though most probably it was not very wide and rather deep and moderately steep. Faint and irregular traces of the suture lines are to be seen which, unfortunately, are too imperfect to be of any use.

The following measurements were taken :—

	Large spn.	Small spn.
Greatest diameter of shell ..	184 ..	90
Greatest width of umbilicus ..	? ..	?18
Greatest height of outer whorl	?85 ..	?
Greatest width of outer whorl..	70 ..	?

Another specimen consists of a small part of the suture line, most likely of an individual closely related to the above ; besides this there are two fragments of whorls and a portion of the external cast that belong to shells of the same species as the preceding.

Those remarkable Ammonities, which have received so much attention on account of the eccentricity of their shapes, are not wanting, for as already stated, we have a portion of a whorl that seems to belong to a *Crioceras* identical with, or closely allied to the *C. Australis* of Moore. (1) [**10102**].

Class Pisces. Sub-Class Selachii.

Vertebrates are also represented in the Gingin Chalk ; one of the specimens in the W.A. Museum collection consists of the tooth of one of the Lamnidæ [**10104**]. This tooth, which has a length of 25 m/m, a width of 8½ m/m at the base, and a maximum thickness of about 6½ m/m, is *Odontaspis*-like in shape, but at the same time,

(1.) C. Moore, Australian Mesozoic Geology and Palæontology, Q.J.G.S., Vol. XXVI., 1870, p. 257, pl. XV., fig 3.

instead of the crown being curved in the usual manner, it is very faintly sigmoid as in the Mesozoic *Orthacodus*. It is evidently a remain of one of the earliest members of the great shark family, now so plentifully represented in Australian waters, and may be the earliest record. The conclusion arrived at by Mr. F. Chapman, of Melbourne, when he saw Mr. W. Howchin's list of the Foraminifera from Gingin, namely that the beds were of Cretaceous age, is confirmed by the collection of Gingin Fossils. The *Serpula*, *Pseudavicula*, *Inoceramus*, *Gryphæa*, and the *Ammonities* have a most decided Cretaceous aspect and, though *Pseuadvicula* and the two genera of *Ammonites* have not been recorded by collectors subsequent to 1897, as far as is known by the Department, there is no reason for doubting that they are obtained from the quarry on One Tree Hill.

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1909.

WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 37.

THE GEOLOGICAL FEATURES

OF THE

Country lying along the Route of the Proposed Transcontinental Railway in Western Australia,

BY

CHAS. G. GIBSON, B.E.,
Assistant Geologist.

Issued under the authority of the Hon. H. Gregory, M.L.A., Minister for Mines.

WITH A GEOLOGICAL SKETCH MAP AND 21 PLATES.

PERTH:
BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.

1909.

PREFATORY NOTE.

The field work on which this report is based was undertaken in connection with the survey of the proposed Transcontinental Railway.

Mr. Gibson commenced his work at Kanowna on August 27th, 1908, and remained in the field until the second of December of that year, having travelled approximately fourteen hundred miles.

The report is divided into three parts dealing respectively with the general geological features, the mineral possibilities, and the subterranean water resources.

The report is accompanied by 21 plates and a general geological map of the area dealt with.

On being submitted to the Hon. the Minister, the report was ordered to be printed for public information.

A. GIBB MAITLAND,
Government Geologist.

Geological Survey Office,
Perth, 19th July, 1909.

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MAP.

Geological Sketch Map of The Country along The Route of the Proposed Transcontinental Railway.

THE GEOLOGICAL FEATURES OF THE COUNTRY LYING ALONG THE ROUTE OF THE PROPOSED TRANSCONTINENTAL RAILWAY IN WESTERN AUSTRALIA.

Part I.—General Geological Description.

The first traverse made in connection with this work was from Kanowna along the surveyed road to the Majestic, *via* Bulong, thence to the end of the Westralian Timber Company's wood line (Kurramia) and eastward along the surveyed line of the proposed railway to Cardinia Rocks (69M).

This traverse showed the centres of Kanowna, Bulong, and Majestic to be within one main greenstone belt which was also proved to be continuous eastward almost as far as Cardinia, and was also subsequently shown to extend northwards beyond Kurnalpi probably as far as Pingin and southerly to the north end of Lake Cowan.*

The greater part of this belt is covered with extensive recent deposits (sands, loam, etc.), this being especially the case east from Bulong and along the proposed line of railway where there are large loam flats extending for miles; these being usually well timbered with salmon gum and gimlet; the nature of the rocks underlying these flats can only be determined by the character of the surface soil.

Some eight to ten miles on the south side of the line the country is more hilly and broken and the greenstones outcrop over considerable areas; it is here that the mining centres of Mt. Monger and Randells are situated.

Immediately along the line of route the only rock outcrops of any note are towards Cowarna Rocks where there are a few low greenstone ridges which, however, are not of any great extent, and appear to be almost free from the occurrence of quartz reefs. These outcrops show the country rock to be a fairly fine grained greenstone more or less foliated and similar to that usually found on the Western Australian goldfields.

The greenstones are intersected by occasional granite dykes and masses, one of the most conspicuous of these being at Cowarna Rocks, this consisting of a bare outcrop of a coarse-grained massive granite of considerable extent.

*This belt is broken here and there by small intrusions of granitic and other rocks, but these are of comparatively small extent, and are generally distinct from the great interior belt of granitic and gneissic rocks -C.G.G.

The western boundary of this main auriferous greenstone belt lies about ten miles to the west of Cardinia and as shown on the accompanying geological sketch map runs roughly north and south; beyond this the country is granitic and non-auriferous, with the exception of a small belt lying immediately to the west and north of Cardinia, which has a width of about three miles and a length of possibly twenty, its extent being as shown on the map attached.

At Cardinia are considerable areas of bare granite rocks forming low hills and giving a splendid water catchment. The whole country about here is more hilly and broken, and in addition to the granite hills there is a series of low greenstone ridges to the west and north.

The granite is undoubtedly intrusive and newer than the greenstones, and several small fragmentary areas of the latter can be seen entirely caught up in it.

At Cardinia water is obtainable in numerous small holes in the granite and also from a soak at the foot of the rocks. The surface holes only last for a few weeks after rain, but there is a fairly good supply in the soak, and though not permanent it can be relied on for the greater part of the year provided the season has been a fairly good one and the water is not drawn upon too heavily.

From Cardinia Northwards.

From Cardinia a traverse was made northwards as shown on the map, for a distance of fifty or sixty miles for the purpose of examining the country in that direction.

For the first couple of miles low broken granite ridges were passed over—greenstone country lying a short distance to the west; after this the greenstone belt was entered upon and crossed in about three miles. This belt appears to run in a north-easterly direction for some fifteen miles; where crossed it consists of alternating low ridges and salt-bush flats, the country rock being a fine-grained foliated and schistose amphibolite, the trend of the foliations being roughly north and south. Quartz reefs are fairly plentiful throughout and some of them are of considerable size and extent; they have received some little attention from the prospector but nothing seems to have been done in a systematic way.

After crossing this greenstone belt the granitic area was again entered on, the country being flat and covered with extensive beds of recent deposits (sands, loam, etc.); up to a point some twelve miles north from Cardinia these flats for the most part support a good growth of salmon gum and salt bush, but beyond this point the timber is mostly mulga with patches of stunted gum and spinifex.

At Beerie, on the west end of Lake Roe, there is a small patch of bare massive granite rocks and at Yindi, some six or seven miles farther north a considerable extent of similar rocks prevails, these being the only two localities where outcrops of any extent were noted.

At these latter rocks (Yindi) there are several good rock water holes and also a couple of shallow soak wells. The rock-holes do not last very long but the soaks are said to be fairly permanent. At Beerie there is a small rock-hole of an estimated capacity of about one hundred gallons.

Soon after passing Yindi greenstone country was again entered on, this being portion of the main Kurnalpi, etc., belt, the eastern edge of which lies a few miles to the west of the line followed and at this point swings out considerably to the east, as shown on the plan herewith.

Where first met with there is a considerable extent of hilly country in this belt, some of the hills rising to a considerable height, *e.g.*, Mt. Quinn, Mt. Charles, Mt. Hunt, etc. This belt of hilly country can be seen running southerly for some miles, Mt. Charnleigh being apparently its southern limit. The rocks forming the hills are fine-grained greenstone of the usual type. Near the main body of granite they are intersected by numerous granitic dykes which are evidently merely offshoots from the main body. Quartz reefs are few and far between and the belt just here is not a promising looking one for the prospector.

After leaving the hills, which only run northerly for a couple of miles, extensive mulga flats are met with which extend in a northerly direction for twenty to thirty miles but are broken here and there by low greenstone ridges.

Lying about twenty-five miles to the north of Yindi is a long narrow salt lake running east and west and apparently draining to the east; this is undoubtedly part of the Mulgabbie series of salt lakes and is probably also continuous with that long narrow lake bed marked on the departmental maps as the Ponton River.

Along the south side of this lake and distant three to six miles from it are a series of low greenstone hills, many of them being covered with a thin capping of ironstone rubble. Through one of these hills which was examined, near the eastern edge of the belt, and possibly also through others, runs a large laminated quartz-hematite lode similar to those found farther north on the North Coolgardie and Mt. Margaret Goldfields. This was the only one of these lodes noted and it is probably the extreme southern limit of the well-marked Edjudina series.*

Approaching their eastern junction with the granite again the greenstones are intersected by dykes and masses of granitic rocks, some of these being of considerable extent; they are apparently all merely offshoots from the main mass to the east.

Although the greater portion of the greenstone belt is covered by extensive beds of recent deposits there are, however, considerable areas over which the rocks outcrop, this being especially the case northwards from Yindi towards the lake previously mentioned. These rocks are for the most part slightly schistose, the foliations being

* See Bulletin XI., G.S.W.A.

roughly north and south. No quartz reefs of any great size were noted but this is not to say that such do not occur; small reefs and leaders are fairly plentiful and although the district has been "run over" by prospectors, it is in my opinion sufficiently promising to warrant further attention from them.

On the return journey to Cardinia the route followed was entirely over granite country, most of it being flat and covered with extensive areas of loose sandy soil, the rocks only outcropping here and there as small isolated patches and being usually very much decomposed and weathered.

By far the greater part of this country is covered with a dense growth of mulga which can be seen extending easterly for a number of miles, gradually giving place to the interminable mallee and spinifex sand plains of the interior.

From Cardinia Southwards.

For the first two or three miles in this direction broken granite and greenstone country was passed over, the track following close to the junction of the two formations; after about three miles the main granite belt was properly entered on and was found to extend unbrokenly over the whole of the country traversed.

From Cardinia the country is, after the first mile or so, mostly loam flats to Erayinia, these being timbered with good salmon gum. On the rising ground around Erayinia the timber is chiefly mulga, but the salmon gum flats can be seen extending westerly for a good many miles.

At Erayinia the granite outcrops over a considerable area in the form of one large and several small round-topped hills; the rock is similar to that at Cardinia, being massive and fairly coarse-grained and very little weathered.

There are several small rock-holes in the granite in which a supply of water can be got after rains, but they cannot be relied on for any length of time.

Some seven miles south-south-east from Erayinia is a second small outcrop of granite in the form of a small patch of flat bare rocks a couple of acres in extent; which is practically the only granite outcrop of any importance noted, the bulk of the country being covered with a considerable thickness of loose sandy soil.

From Erayinia to some two miles beyond this second patch of rocks the country is flat and mostly timbered with stunted mulga; beyond this latter point mallee and spinifex covered sand plains and ridges come in and are then continuous southerly as far as my traverse went and as far southerly and easterly beyond this as could be seen with powerful field glasses. A few miles to the west the country is slightly better as the spinifex dies out and the timber improves somewhat, consisting of mixed salmon gum, gimlet, and giant mallee.

Some ten miles south-south-east from Erayinia are a couple of small salt lakes which are probably more or less continuous with the

well-marked series met with some twenty miles farther south. This latter series consists of a number of lakes, from a few chains up to half a mile in width, all more or less connected—the separating country being usually drift sand—and having a general trend to the south-west, the drainage also being in this direction; these lakes are evidently continuous into Lake Cowan, and they form the main drainage channel for the whole of this district.

Along the western side of one of the lakes at a point about eighteen miles south of Erayinia the greenstones were again noted. This is evidently the eastern edge of the main belt. The actual junction between them and the granite cannot be followed owing to the covering of recent deposits but it appears to run here about north and south.

The greenstones can be seen outcropping along the western side of the lake for a distance of a couple of miles; they are very much weathered and are highly foliated, the foliations running slightly west of north and east of south. Several quartz reefs of considerable size were noted in them; these are of white barren looking quartz, and as far as could be tested were devoid of gold; they run about north-north-west and south-south-east and are fairly persistent in their strike.

A short distance westward from the lakes the country is again all covered with recent deposits and no outcrops are visible.

From Cardinia Eastward to the 102-Mile.

The whole of the country between these two points is granitic and as usual is mostly flat and covered with the usual loose sandy soil. At Jumannia and a few miles to the west of it are small patches of bare granite rocks, which are the only outcrops of any note until about the 101-Mile peg is reached when a few low granite ridges are met with; these extend over a width of about a mile and run northerly for some distance.

Northwards from the 102-Mile.

A traverse was made from the 102-Mile in a northerly direction as shown on the map. The result of this was to prove that the country in this direction was all granitic, practically the whole of it being covered with loose sand and clothed with dense mallee and spinifex, with the exception of a small area crossed on the return journey and extending ten or a dozen miles north of the 123-Mile peg on the surveyed line.

Starting north from the 102-Mile the country for the first few miles is flat and timbered with stunted gum; after this it becomes somewhat undulating, consisting of alternating hollows and long low ridges, the whole being covered with dense mallee and spinifex. The general trend of the valleys is slightly north of east and the drainage from them appears to be in this direction.

This class of country was continuous to the Ponton River and east and west of the route followed as far as could be seen.

The Ponton River, as it is called on the departmental maps, is a long narrow salt lake, or chain of lakes, draining to the south-east; where crossed it was from three to four chains in width, which is apparently about its average size. The course of these lakes is along a wide deep well-defined valley and they probably mark the remains of what was once a very fair-sized river flowing in tertiary times into the sea which then covered that portion of the country now occupied by the Eucla Limestone Tableland. It is probable also that other series of lakes, *e.g.*, those near Buninginia and Newman's Rocks, as well as Lakes Cowan and Lefroy, were connected with the sea at a similar geological period: Lake Cowan undoubtedly at that time formed a large tidal estuary, as the discovery of Tertiary beach remains and sponge spicules in the so-called deep lead at the Princess Royal, Norseman, proves.

The drifting sand hills of the interior are gradually encroaching on the old bed of the Ponton and it is only a matter of a comparatively few years until it is completely obliterated. At the present time it is marked west and north of the point where crossed by a series of narrow salt lakes, connected by a sandy watercourse which could be seen trending north-westerly for many miles and which are probably continuous with the Mulgabbie series of lakes; south-easterly it gradually lapses its lake-like nature and becomes merely a sandy watercourse which varies from a half to three chains in width. In this direction it runs for about a hundred miles before dying out on the plains and for the latter part of its course is known, and is shown on the departmental maps, as Goddard's Creek.

A few miles on the north side of the Ponton along the route followed is some very high country which however is not conspicuous owing to the fact that most of the surrounding country also lies at a considerable elevation being 1,400 to 1,500 feet above sea level and several hundred feet higher than the country to the south along the surveyed line. There are several outcrops of bare granite rocks over this high country but they are of no great extent, most of the country being covered with a considerable thickness of loose sandy soil. There is a small rock-hole holding about 100 gallons from which water can at times be obtained on one of these outcrops some three miles or so north of the Ponton, this being the only water noted. A large amount of "narrow-leaf" poison bush was noted round these granite rocks; other localities where it was noted in any quantities were Queen Victoria Spring, and here and there, along the banks of Goddard's Creek; it was also noted on the coast near Twilight Cove, long. 126 E.

From the highest point from which a general view could be obtained, the country as far as could be seen with field glasses consisted of alternating low ridges and valleys all covered with a dense growth of mallee and spinifex.

Along the route followed southerly back to the survey line at a point some two miles or so south of the Ponton River are a few small outcrops of weathered granite and several small weathered granite "breakaways," which were the only rock outcrops seen on the journey south.

Sand plains and ridges covered with dense mallee and spinifex continue unbrokenly for some fourteen miles south from the Ponton; beyond this point and extending to the survey line are extensive flats covered with scattered salmon gum and gimlet interspersed with patches of mallee and spinifex, which class of country extends back westerly to the 102-Mile peg (*i.e.*, from the 123-Mile peg).

From the 104-Mile to Buninginia and Goddard's Creek.

For the first half dozen miles the country consists of salmon gum, gimlet, and salt and blue bush flats after which there are three miles or so of mallee and spinifex; at the end of this and about nine miles from the line are several small low ridges with outcrops of weathered granite, and one small isolated flat-topped hill. This hill is capped with six to ten feet of vitreous quartzite, this being the result of the decomposition of the underlying granite, and similar to that found as hill cappings on the Murchison Goldfield. Round this hill are salt bush and grass flats which extend south-easterly for several miles; patches of salmon gum also occur along the edges of these flats.

About four miles south-easterly from the flat-topped hill are salmon gum, gimlet, and salt bush flats which extend for some six miles when they give place once more to mallee and spinifex country, which is then continuous from west round through south to east as far as the eye can reach.

At Eudarie, some 20 miles south-easterly from the 105-Mile peg, are several fair-sized outcrops of bare massive granite, these being several acres in extent. On the largest of them is a rock-hole holding after rains some 200 gallons of water and there is also a small soak at the foot of the rock but the supply is not permanent.

There is a small patch of good country immediately around these rocks but beyond this the mallee and spinifex is continuous as far as can be seen.

Between Eudarie and Buninginia (18 miles) the country is all mallee and spinifex with occasional patches of stunted gums. Some five miles from the former place is a narraw salt lake in a small valley, falling east-south-easterly with spinifex and sand ridges on either side of it and four miles farther on is another narrow lake, or series of lakes, draining south-easterly.

On the north side of this lake is a small outcrop of weathered gneissic granite which is the only rock outcrop noted until the gneiss country near Buninginia was reached. There is a small soak at the foot of these rocks, near the edge of the lake, but it does not look as if it would be in any way permanent.

A mile or so northerly from Buninginia are several low ridges of gneissic granite which trend about north-east and south-west and are for the most part covered with loose sandy soil and densely clothed with spinifex.

At Buninginia there is a large open salt bush and grass flat running south-westerly which is about a mile in width. There is a small flat outcrop of gneissic granite on this flat about half an acre in extent, and on this there is a natural rock-hole holding after rains about a thousand gallons of water. South-westerly from here the salt bush and grass flats with oaks and patches of myoporum are said to extend, with only slight breaks, to Simon's Hill; there is, however, only a narrow strip of this class of country and it is shut in on both sides with mallee and spinifex.

Travelling north-easterly from Buninginia to Goddard's Creek the country for the first six miles consists of loamy flats with oaks, gums, blue bush, and patches of salt bush and grass; at this point (six miles from Buninginia) half a mile or so of lake country is met with, the main lake being a long narrow one only a few chains in width draining south-easterly; over this lake country are salt bush and grass flats. A short distace on the north-east side of the lake a number of pegmatite dykes outcrop which have a roughly parallel trend and vary from a couple of feet up to half a chain in width; they are found over a stretch of nearly a mile and occur in an area of gneissic granite, mostly covered with sand, and are very persistent and regular in their strike. They are coarse-grained and carry a considerable amount of tourmaline, as also does the enclosing gneiss. This locality struck me as one likely to prove tin-bearing, though a brief trial of several of the dykes failed to prove its existence, for the geological conditions are identical with those prevailing on most of the known tinfields.

Outside the main auriferous belt and the smaller one near Cardinia, this, with its southerly continuation, was the only piece of country passed over with even a possible chance of mineral wealth and although the results of the trials made were negative it does not follow that a more detailed search than was possible* may not reveal the presence of mineral deposits, though the chance of this is, I think, a rather remote one.

The gneiss of Simon's Hill and Fraser's Range seems to be portion of this same belt and in the former locality pegmatite dykes similar to those above mentioned were noted but not in the same numbers. On Goddard's Creek some forty miles slightly east of north from Buninginia a small outcrop of a similar gneiss was noted which was apparently the northern continuation of the same belt.

After leaving the lake country there are, in the direction of Goddard's Creek, some six or seven miles of oak and gum flats with

*As my equipment for the carrying out of the whole of this work consisted only of two camels, and my water-carrying capacity was only twelve gallons I was unable to travel as freely as I could have wished, or to spend as much time as I would have liked in certain localities.—C.G.G.

scattered salt and blue bush, and then mallee and spinifex with patches of stunted gum; this latter class of country being continuous easterly some twenty miles or so beyond Goddard's and southerly as far as the eye could reach.

Goddard's Creek, where first struck, is some twenty-seven miles from Buninginia and is running almost due east and west, its bed being from one to three chains in width and formed of loose drift sand. For the whole of the distance traversed it runs through sand plains with dense mallee and spinifex which, as a rule, comes right down to the banks. Here and there along the banks are small patches of wattle and other stock bushes but these, however, are only of a few acres in extent.

From the point where it was first struck the creek was followed west and north to the point where crossed by the survey line, and subsequently traversed some twenty to thirty miles beyond this point for the purpose of proving its connection with the Ponton River.

Goddard's Creek was formerly similar in appearance to what the Ponton River now is farther to the north-west, viz., a typical narrow salt lake with the usual salt gypseous clay bed which has gradually become covered over with drift sand and can be exposed anywhere by digging a few feet down in this sand. The fresh water soaks which are found at fairly frequent intervals along the creek are merely supplies of rain water held in the sand on this clay bottom and are by no means permanent; in digging them out, if the clay bottom is opened up at all, the water rapidly becomes salt, as it also does if drawn upon too heavily.

After leaving the lake country near Buninginia no rock outcrops of any description were seen on the journey to Goddard's and along it to the survey line, the whole country being covered with considerable deposits of sand.

From Goddard's Creek to Queen Victoria Spring, and thence North-East.

From the point where the survey line crosses Goddard's Creek a journey was made to Queen Victoria Spring and thence north-easterly for some distance, for the purpose of examining the auriferous country which had been reported to exist in the locality. My investigations, however, failed to reveal the slightest trace of mineral country in the vicinity of the route traversed, and though such *may* exist—I could not examine every inch of the country—its extent must be so small as to render it of no importance; for my own part I am of opinion that there is no mineral country within, at least, thirty miles of Queen Victoria Spring.

Up to a point about fifteen miles from the spring the country was practically all sand flats covered with a dense growth of mallee and spinifex, the only exceptions being a few small isolated patches of salmon gum a few acres in extent, which were chiefly found between fifteen and twenty miles from Goddard's.

Drifting sandhill country commences at a point fifteen miles from, and is then continuous up to, the spring and also extends for many miles both north and east from it. It is covered with spinifex and carries a few desert gums and pines with occasional small patches of wattle.

Between Goddard's and the spring the only rock outcrop seen was a small patch of weathered granite about a quarter of an acre in extent lying some twenty-two miles along the track.

Queen Victoria Spring is not a spring in the correct sense of the term, it being merely a soak situated in the centre of twenty to thirty acres of grass land surrounded by pines, desert gums, mallee, and spinifex. The soak is in sand on a clay bottom and is apparently formed in an old claypan which has been filled in by drift sand. There was a good supply of water in it when I was there, but it is said to give out after a bad season; it is situated just on the west side of the sand hills and about nine miles west-north-west from Streich Mound. To the south and round through east to north and north-west the country is all sandhills, but to the west and south-west it consists of mallee and spinifex plains which extend across to within a comparatively few miles of Mt. Quinn and Mt. Charles.

Streich Mound is a large round-topped sandhill and is easily the highest point in the district, forming a good guide to the soak, as it can be seen from any high point up to twenty miles distant.

As a general rule the sandhills form long irregular ridges trending roughly east and west and having an average height of fifty to seventy feet, occasionally much more, and the distances between the ridges vary from a few chains up to half a mile or more. Between Streich Mound and the spring, however, the hills have no particular trend but are dotted about all over the place and travelling across them is very heavy on that account.

From Queen Victoria Spring a traverse was made north-easterly, as shown on the map herewith, as it was in this direction and distant about twenty miles that the auriferous country was supposed to exist. My investigations showed all this country—and a good deal beyond it—to be practically all sand hills and certainly not auriferous.

On the outward journey, *i.e.*, going north-east, the country passed over was all sand hills covered with spinifex, desert gums, and pines, with occasional patches of dense mallee. For the first eight or ten miles the sand hills were large and numerous, generally having an east and west trend, but beyond this they got smaller and fewer though they could be seen thick enough a few miles to the north. The flats between them are usually covered with dense mallee and spinifex, the growth over the hills themselves being much more scattered.

From the top of a high sandhill (a) eighteen to twenty miles from the spring, sandhill country could, with the aid of powerful field glasses, be seen extending away indefinitely to the west and

round through north to east; in the latter direction there were twelve to fourteen miles of mallee flats before the sandhills commence.

From this sandhill (a) I went to a second one (b) lying about twelve miles east-south-east, the intervening country being all flat and covered with a dense growth of mallee and spinifex, while at one spot about two miles on the way there was a small outcrop of weathered gneissic granite which was the only rock outcrop seen on this journey. From the top of the second hill (b) sandhill country could be seen extending away indefinitely to the north and east.

Returning from (b) to the spring about ten miles of mallee and spinifex flats, broken in one or two places by small patches of salmon gum with salt and blue bush, were crossed, after which the sand hill country started again and continued to the spring.

On the return journey to the survey line we travelled due south from the spring for a distance of thirty miles, at which point Goddard's Creek (Ponton River) was struck and this was then followed down south-easterly to the point where crossed by the survey line. At a point some six miles from the spring two low sand ridges running east and west were crossed, the balance of the country being practically flat with a general fall to the south and east and covered with dense mallee and spinifex, with the exception of two or three small isolated salmon gum flats each only a few acres in extent. There is generally fair salt bush on these flats and they are the only areas over which any stock feed is procurable.

Goddard's Creek (the Ponton) where first met on this traverse is in a deep well-defined valley which is deeper and better defined to the north-westward where the country is higher; south-easterly the country is falling and the hills and ridges which form the sides of the valley gradually die out in this direction so that a few miles above the point where crossed by the line, and south-easterly beyond it, the creek is merely running through a sandy plain. Its bed varies from two to four chains in width and where first struck the salt-lakelike appearance which it has farther north-west is just disappearing beneath drift sand. A few small patches of gypseous clay and salt still are visible along the bed, but a few miles farther south-east these disappear and the bed is entirely covered with loose drift sand overgrown in places with mallee and ti-tree. The first fresh water soak is found in the sand some ten miles north-west of the line but is not good, the quality of the water and also the supply improving farther to the south-east.

The general trend of the creek from where first met with to the point where crossed by the survey line is roughly south-east and the country through which it runs is of the poorest description, consisting almost entirely of sandplains covered with dense mallee and spinifex. However, there are occasional small areas immediately along the banks of the creek where a little stock feed is procurable, this being mostly wattle and salt bush with here and there small

patches of grass; where these occur the "narrow-leaf" poison plant is also very plentiful.

Some fourteen miles north-west from the line and along the south-west bank of the creek is a low ridge of weathered granite (gneiss) and along the banks of the creek itself is a small outcrop of garnetiferous gneiss which is practically identical in appearance with that noted at Buninginia, Simon's Hill, and Newman's Rocks, and is evidently the continuation of that belt. Owing to the recent deposits (sands, etc.) which cover most of the interior country the extent of this gneissic belt and its relationship to the massive granites farther west could not be determined; it may only be a part of this massive granite which has been rendered gneissic by local pressure, etc., or it may represent an older and entirely different series, and personally I am inclined to the latter belief.

From Goddard's Creek East to the 280-Mile, thence South to the Coast at Eyre, and thence via Balladonia to Simon's Hill.

Going easterly from Goddard's Creek along the proposed line of railway, the sandplain country with mallee and spinifex continues for some twenty-three miles, *i.e.*, to about the 167-mile peg. At one or two places small patches of gimlet wood with salt and blue bush occur within this mallee and spinifex belt, notably near the 157 and the 163-mile pegs. East of the 167-mile peg the mallee and spinifex give place to oaks and blue bush with scattered salt bush, whilst the sand plains are replaced by light-coloured loam flats. This change marks the approximate junction between the granitic country and the tertiary limestone which from this point is continuous easterly across the South Australian border and southerly to the coast. No rock outcrops are visible for a number of miles both east and west of this point (the 167-mile) and as the change in the surface deposits and in the vegetation is a very gradual one and no natural sections could be observed, it is difficult to define exactly the junction between the two formations but it probably runs approximately as shown on the map herewith.

The whole of this limestone area is practically dead level, or at the most slightly undulating, and is covered with a varying depth of light-coloured loam from beneath which flaggy limestone can be seen outcropping every here and there. Along the proposed line of railway there are on this area vast treeless grass and salt bush plains, but nearer the coast there is a fair extent of timbered country.

Over the limestone country the only surface water procurable is obtained from small "rock-holes" which are few and far between, and at best are of very limited capacity. The positions of the principal ones are shown on the map herewith and a fuller description of them will be given later. In addition to the " rock-holes" there are found numbers of what are known as "blow-holes," which are more or less circular openings in the limestone crust from two to six feet

in diameter, through which the air often rushes with considerable force; sometimes the draught is inward and at others outward, consequent on the difference of temperature outside and in. The occurrence of this "blowing" indicates the existence of a system of underground air passages.

Over certain areas in the limestone country there occur also shallow circular depressions in the surface which have been locally termed "dongas"; these vary from five to twenty chains in diameter and are undoubtedly formed by the caving in of subterranean chambers in the limestone.

The southern edge of the limestone tableland is marked by a fairly regular line of cliffs which, westerly from Twilight Cove almost to Israelite Bay, form the coast line and rise vertically out of the sea to a height of 250 to 300 feet. Easterly from Twilight Cove they run back inland from the sea for some miles and then trend roughly parallel to it as far as a point some few miles east of Eucla where they again form the shore line, their greatest distance from it being at a point about half way between Eyre and Eucla where they are some thirty miles inland. They form a more or less vertical escarpment some 200 to 250 feet in height, the country between them and the sea being low-lying loam flats with white drifting sandhills along the immediate sea front. At Eyre these sand hills extend inland for some miles and are formed of very fine white sand; they move comparatively fast and are continually encroaching on the telegraph line, having completely buried the original posts in one or two places.

The cliffs where examined at Twilight Cove are seen to consist of soft shell limestone, apparently horizontally bedded, the upper few feet being very hard and compact, this evidently being due to atmospheric influences. In the faces of the cliffs some distance back from the sea and considerably above its present level, waterworn caverns and wave markings show that at one time the coast here was at a considerably lower level than it is at present and that it has risen at a comparatively recent date.

At the foot of the cliffs at Twilight Cove and in the hollows in the sandhills both here and at Eyre good fresh water is obtainable a foot or two below the surface. The occurrence of this water is referred to later on in Part III. of this report.

On the return journey from Eyre the first change in the formation of the country is noted at Balladonia where the granite rocks again make their appearance, outcropping from beneath the limestone. Their occurrence is in the form of a bold bare outcrop rising to a height of fifty or sixty feet above the surrounding plains and covering an extent of, perhaps, a couple of hundred acres. This granite is a coarse-grained massive variety, its essential constituents being quartz, microline, and biotite with a little magnetite; it contains no garnets. Small veins of pegmatite can be seen traversing the

main mass in all directions, varying in thickness from a fraction of an inch up to nearly a foot.

No actual junction between the granitic rocks, and the limestone, beneath which they dip on all sides at a flat angle, is visible owing to the recent deposits which cover the surface of the country, but there is no doubt as to the granite being the older rock. Several other similar isolated patches of granite occur before the main body is reached, notably at Womberna, twelve miles south of Balladonia, Gerandilla nine miles west, Booma Rocks, Wahgoninya Rocks, etc.

An interesting fact in connection with these granite rocks has been the discovery of diprotoden bones (*Diprotodon Australis*) buried in the sand and silt beside them. Discoveries of these bones have been made at Balladonia, at Cook's Rocks, twenty miles north and at Womberna Rocks, twelve miles south. At Balladonia, bones in a good state of preservation were discovered at depths of from four to twelve feet whilst excavating a dam beside the rocks, while at Cook's and at Womberna fragments of bones were found at from four to eight feet from the surface also whilst excavating dam sites close to the rocks. It is evident that the rocks formerly formed watering places for these animals, as they still do for the present-day fauna, and that the bones are the remains of animals that have either been bogged while at the waters or that have perished as the result of the supply giving out after a bad season, as it still does. It is quite likely therefore that search round any or all of these rocks would result in the further discovery of many of these remains.

Travelling from Balladonia towards Simon's Hill the limestone (plain) country extends for about twenty-four miles, being broken by two small outcrops of bare massive granite eight miles and fifteen miles respectively from Balladonia. The former of these (Booma Rocks) occupies an area of about thirty acres and the latter (Wahgoninya, or "15-Mile" Rocks) slightly more, the granite in both cases being similar to that at Balladonia. Over the limestone area the only rock outcrops are in the form of small isolated patches of flaggy limestone, the bulk of the country being covered with a fair thickness of loose light-coloured loam. Owing to this covering of surface soil no actual junction between the limestone and the main granite belt can be seen and as the change from the light loam of the limestone plains to the sand of the granite country is a very gradual one, this junction can only be fixed approximately; probably however it lies some nine miles west of Wahgoninya Rocks as at this point the gum and salt bush country—here characteristic of the limestone—dies out and gives place to mallee, stunted gums, and patches of spinifex which are characteristic of the granite country. Some four miles beyond this point westerly are several small outcrops of gneissic granite, which were the first outcrops noted after leaving Wahgoninya.

About a mile east of these outcrops is a small narrow salt lake draining to the south, the country on each side consisting of low sand ridges with mallee and spinifex: this class of country is then continuous until Newman's Rocks are met with; here there is a considerable outcrop of granitic rocks which occupy an area of sixty or seventy acres and rise in places up to fifty or sixty feet. The rock is a garnetiferous biotite gneiss and is similar to that noted on Goddard's Creek.

On the east side of these rocks is a series of narrow salt lakes which have a total width of about half a mile and drain towards the south, evidently extending for a considerable distance as they can be seen some miles to the north-east and are here in a well-defined, though not deep, valley.

There are several shallow soak wells at the foot of the rocks and a small patch of good country round them, but at a very little distance the sand plains with mallee and spinifex start again and are then continuous almost to Simon's Hill.

Around Simon's Hill there are a number of low-rounded hills and ridges which are the north-east end of Fraser's Range and rise at their highest point a hundred and fifty to two hundred feet above the plain. The rock of which these hills are formed varies from a garnetiferous quartz schist to a garnetiferous biotite gneiss and is evidently a continuation of the Buninginia-Goddard's Creek gneiss belt. Several coarse-grained pegmatite dykes were noted running through the gneiss and one of these some six miles south-east of Simon's Hill has been opened up to a depth of six or eight feet in a couple of places, evidently in a search for mica, masses of which, up to two or three inches square, are common enough in the dyke, which is from six to ten feet in width; fair-sized crystals of tourmaline are also common in it, and one small pink one of poor quality was also noted.

From Simon's Hill to Lake Cowan, Binyerinyina and Kanowna.

After leaving Simon's Hill the country is—with the exception of one small patch of granite rocks—all undulating sand plains, mostly covered with mallee and scattered spinifex, until Lake Cowan is reached. The granite of which the above patch of rocks is formed is of the massive variety as are all the outcrops noted to the west of this point. Some nine to ten miles from these rocks, towards Lake Cowan, a small salt lake was crossed and a second larger one some nine miles farther on; the latter being apparently an offshoot off the northern portion of Lake Cowan; both these lakes are draining to the south and south-west.

Round the north-east end of the main body of Lake Cowan are low ridges of drift sand covered with stunted pine trees running back a quarter to half a mile, and behind them, extending back a couple of miles from the lake, are sand and loam flats. A narrow

arm of salt lake, often less than a chain wide, winds through these flats at the north-east end of the main body of Lake Cowan and unites it with another good sized series of salt lakes lying a few miles to the north-east.

On the north side of this arm the greenstones were again met with for the first time after leaving Cardinia; here they outcrop over a small area and are highly foliated and much weathered, and numerous granitic dykes can be seen running through them, these having a general north-west and south-east trend. Only a narrow strip—about a mile or so—of these greenstones was passed over, the track soon coming on to the granitic area again; they mark the south-western extremity of the main Randells-Bulong-Kurnalpi belt, the boundary between them and the granitic rocks being approximately as shown on the map herewith.

At Binyerinyina is a large outcrop of bare granite rocks which are of the usual massive variety; they lie a couple of miles from the west shore of Lake Cowan and rise from an extensive open sandy flat to a height of fifty or sixty feet. There is a good supply of water in shallow soak wells at the foot of these rocks.

After leaving Binyerinyina no rock outcrops were seen until a point some six miles to the north was reached; here there are a few low broken ridges of granite trending east and west and extending north for about four miles, where they reach their highest point; up to here the drainage of the country is all southerly into Lake Cowan, but beyond this it is northerly to Lake Lefroy. After crossing these ridges no further rock outcrops were seen until the north side of the lake country was reached, when the greenstone of the main belt were met again, outcropping along the shores of the lake, and then at frequent intervals right across to the survey line.

Twenty-five miles north from Binyerinyina a series of salt lakes was met with which extend over a width of about six miles and trend east and west, being evidently a continuation of Lake Lefroy; the widest extent of actual lake bed is about two miles—this being the northerly arm—while there are several other arms over half a mile across.

After crossing the lake country the route followed lay entirely over greenstone country, this being the main Mt. Monger-Randells, etc., belt. The greater portion of the belt where crossed is covered with extensive recent reposits (loam, etc.), but a few miles both east and west of the track are low broken ranges over which the rocks outcrop and in which the mining centre of Randells and Mt. Monger are situated.

Some three or four miles before the survey line was reached a small belt of granite country was passed over, but owing to the recent deposits the boundaries of this belt were not exactly definable, though it appeared to be about a mile across and is evidently only a small offshoot from the main body farther east. One or two somewhat similar but smaller bodies of granitic rocks were

also noted between the end of the wood line (32-mile) and Kanowna, but these, however, are of no great extent or importance.

Part II.—Mineral Possibilities.

As regards the mineral possibilities of the country lying within, say, a 70 to 80 mile radius of the proposed line of railway, it can be stated at once that both the granitic and the limestone formations which, as can be seen by reference to the map, occupy the whole of the country passed over after the first seventy miles, are non-auriferous and, with the exception of the one district mentioned below, hold out no possibility of the discovery of mineral wealth of any description.

This one excepted district is that occupied by the belt of garnetiferous gneissic granite which outcrops at Simon's Hill, Buninginia, Newman's Rocks, and Goddard's Creek. The whole of this belt, however, with the exception of comparatively small areas at the localities mentioned, is covered with extensive sand plains which render it valueless for prospecting purposes. At Simon's Hill and in the vicinity of Buninginia numbers of coarse-grained pegmatite dykes can be see cutting through the gneiss, being especially numerous at a point some half dozen miles north-east from Buninginia. These dykes carry a considerable percentage of tourmaline, as also does the enclosing gneiss, and from their appearance, etc., struck me as being possibly tin-bearing, though a somewhat short examination of them failed to show any.

When passing through Balladonia a specimen of allanite (silicate of lime, iron, aluminium, and cerium) was handed to me which was reported to have been found in one of these pegmatite dykes near Simon's Hill; this mineral, though of itself of no great commercial value, is of considerable scientific interest, but I was unable to ascertain if it were present in the dyke in any quantity, but the probability is that it was not. It is quite probable that where it was found the closely related mineral gadolinite will also be obtained, but this, although it has at the present time a considerable market value on account of its yttrium contents, can hardly be looked upon as a commercial mineral in the general sense of the term.

Near Simon's Hill also, as mentioned in the first part of this report, one of these dykes has been opened up to a depth of six or eight feet in two or three places apparently in search for mica; irregular masses of this up to a couple of inches square are common in the dyke, but as far as opened up it is of poor quality and of little or no value. In this dyke also a small pink tourmaline was noted; these when of good quality are of considerable value as gems, but the likelihood of their being found here in payable quantities is not great.

As, however, neither tin nor any other commercial metal or mineral has been found in it in payable quantities and the possibility of their existence is after all only a faint one, I am not inclined to consider this belt of country as a mineral one, and will say that, in my opinion, the only country of any mineral value lying within at least a seventy-mile radius of the proposed line of railway is that found within the first sixty-nine miles of the surveyed line. This embraces the two greenstone (auriferous) belts mentioned in the first part of this report and shown on the map herewith, viz., the main Kurnalpi-Bulong, etc., belt and the small belt lying west and north of Cardinia.

This second belt has a probable length of some fifteen miles and an average width of about three miles. The rocks are greenstones of the usual type and are somewhat foliated and schistose; quartz reefs are fairly plentiful and are sometimes of considerable size. The belt has been run over by prospectors, but no systematic prospecting has been done, and the general appearance of the locality certainly warrants more attention than it appears to have received.

The extent of the first, or main, belt is shown on the map accompanying this report, and, as can be seen, the whole of this district is within fairly easy access of the various outlying settled centres —Kurnalpi, Bulong, Kurramia (Wood line), Randells, and Mt. Monger—and has received considerable attention from the prospector. There is, however, within it a considerable extent of country which is well worthy of further attention, this being particularly the case with that portion lying to the east and north-east of Kurnalpi; here some very nice looking country was passed over which, judging by appearances, has not received much prospecting.

It can, however, hardly be said that either of these belts are "new" country for they have both been known to, and have received attention from, prospectors for a good number of years back. Neither can it be said that the construction of the proposed railway will to any great extent tend to open them up for the most outback portion of them is, as before stated, within fairly easy access of already settled centres, and in view of this fact it can be said that, broadly speaking, the construction of the proposed line will open up no mineral country.

Part III.—Water Supply.

Relative to the water supply along the proposed railway, it can be briefly stated that the whole of the first hundred and eighty miles is practically a waterless stretch; there are certainly a few rock holes and soaks along it, but these are not permanent, and the supply is very limited. Moreover, boring operations have so far failed to prove the existence of an underground supply of fresh water and, as far as the country travelled over by myself goes,

I hardly think a supply is likely to be found, *i.e.*, before the limestone country is entered upon, unless it be at a spot about eight miles south of the 115-mile peg on a large salt bush and grass flat at the south-east end of a well defined watercourse falling in this direction. There appears to be a good drainage from at least three sides into this flat, and it was the only place seen by me which gave even a faint hope of the possibility of obtaining fresh water at a fairly shallow depth.

Salt water will, of course, be procurable at a shallow depth along any of the systems of salt lakes.

As regards a supply for the railway over this first stage, the only way of procuring it will be by the construction of tanks and the conservation of the surface supply (rain water) and practically the only place along the line where a decent tank site and catchment is available is at Cardinia Rocks (69-mile).

Along the section of the line lying over the limestone tableland, water will always be procurable by deep boring, but the quality will, judging by previous results, possibly not be too good, and, in addition, it will in all probablity have to be pumped from a depth of several hundred feet, owing to the flow not reaching to the surface for reasons given below.

The strata of which this tableland is formed consists of porous tertiary limestones, with underlying soft sandstones and clay shales ; these beds appear to me to be laid down practically horizontally, though a slight prevailing dip to the south, *i.e.*, towards the coast, has also been ascribed to them. On the north the water-bearing beds do not outcrop, but presumably impinge directly on the granitic rocks, and receive a large portion of their water along this junction.

On the South Australian side of the border, bores show that the upper sandy water-bearing beds are overlain by three hundred to five hundred feet of porous limestone ; these water-bearing beds outcrop at sea level, and being practically horizontal, are also overlain on the Western Australian side by two hundred and fifty to three hundred feet of limestone (the height of the cliffs) near the coast, which increases to five to six hundred feet farther inland owing to the gradual rise of the surface of the country. A second main water-bearing series appears to exist at a depth of 1,000 to 2,000 feet below the upper one, the intervening porous rocks also being more or less saturated with water. The occurrence of this lower water-bearing series is proved by the bore at Madura (W.A.), in which a flow of water was struck at a depth of a little over 2,000 feet and rose to the surface.

This lower series could be tapped by bores anywhere inland within the limestone area, but, owing to the fact that the surface of the country varies from 250 feet, at the cliffs on the coast, to 550 feet, along the railway line, above sea level, and also that there is a known outlet for the water along sea level—proved by the presence of surface springs at the foot of the cliffs at Twilight Cove

and on the shore at Eyre—the probability is that the water will not rise to the surface, though there will probably be sufficient pressure, due to the natural resistance to horizontal flow, to make it rise considerably above sea level. The bore at Madura is stated to be put down at the foot of the cliffs, a very few feet above sea level, and the flow, even here, is only a foot or so above the surface ; the supply is put down at 5,700 gallons per day (from 2,040 feet) and is said to be good stock water.

In five bores put down on the South-Australian side of the border, water was met with at depths of from 700 to 1,200 feet, but in no case did it rise to the surface ; the supply varied from strongly brackish to good stock water.*

A bore put down at a point twenty-five miles north of Madura struck the upper water-bearing series at about 430 feet (about sea level), and the supply is said to be good stock water, but it has to be pumped from the bottom of the bore. This upper series will be met with over the whole basin at about sea level, the supply will be plentiful and probably of better quality than that met with at the greater depth ; it will however not rise to the surface and will always have to be pumped.

In connection with the question of artesian or sub-artesian water in this district, the following extracts are taken from a report† by the Government Geologist of this State written in 1900 and from a report‡ by the Government Geologist of South Australia written in 1885. The first of these reports reads as follows:—

". . . . . The strata consist of porous limestone associated with beds into which the rainfall is rapidly absorbed and discharges seawards in the form of fresh water springs, rendering the occurrence of underground water more than probable. These beds have been pierced by means of live bores on the South Australian side of the border. The section in these bores invariably shows a thickness of sandy water-bearing beds covered by limestone from 300 to 500 feet thick. The beds have a slight prevailing dip towards the Great Australian Bight, and the water (sub-artesian) rises in the bore holes to a height equal to that of the sea level. So far, however, the water obtained has proved to be either salt or brackish, but still suitable for stock purposes . . . . I am, however, not very sanguine of success in obtaining anything but a sub-artesian supply of water anywhere towards the northern edge of the Tertiary basin. Any such supply would be expected to be at least brackish though no doubt suitable for stock . . . "

In the second report Mr. Brown says:—

" . . . There is every probability of good water being obtained by boring through the limestone of the Nullabar Plains into

* See Annual Report of the Geological Survey, 1900, pp. 29 and 30.
† Extension of Artesian Water-carrying Strata from South Australia : by A. Gibb Maitland, Government Geologist. Annual Report Geological Survey, W.A., 1900, p. 28.
‡ A Report on the Geological character of the country passed over from Port Augusta to Eucla : by H. Y. L. Brown, Government Geologist, Adelaide. By authority, 1885.

the sandstone, clay, and sand beds which will be found beneath it. It is not probable that water met with in boring here will rise to the surface, taking the high elevation of the plain into consideration and the certainty that outlets exist to the southwards where the sea level is from 250 to 300 feet lower than the surface of the plain. Sufficient pressure might, however, remain to force the water to a considerable height in the bore . . . . ."

Over this limestone tableland the only surface water procurable is found in small rock holes which are more or less circular holes worn in the upper crust of the limestone and holding up to, in one case, 20,000 gallons of water; their more usual capacity is, however, from 500 to 1,000 gallons. They hold water only for a comparatively short time after rain and are not to be relied upon for a supply during the summer months; and at best they are but few and far between.

The positions and holding capacity of the most important of these rock holes are shown on the map accompanying this report.

With regard to the supply of surface water over the route followed by myself along and away from the survey line, the following are descriptions of the principal rock holes and soaks, exclusive of those in the limestone and along the stock route which are shown on the map:—

Cardinia.—Several small rock holes and soaks at foot of large granite rock. Good supply of fresh water during the greater part of year, but it is said not to be permanent.

Jumannia.—Rock holes. 2,000 gallons.

Erayinia.—Small rock holes; supply poor. Small rock hole (100 gallons) 7 miles south-south-east.

Beerie.—Small rock hole; 200 (?) gallons.

Yindi.—Good rock holes and shallow soak wells; supply good.

Ponton River (*North side*).—Small rock hole; 100 gallons.

Eudarie.—Rock hole, 200 gallons, and small soak at foot of rock.

Buninginia.—Rock hole, 1,000 gallons. A small soak at edge of lake half-way between Eudarie and Buninginia.

Goddard's Creek.—Numerous soaks along the sandy bed of the creek; supply good, but is said to give out after a bad season.

Queen Victoria Spring.—Soak in sand on clay bottom; good supply in average seasons, but is said to give out after a bad one.

C. G. GIBSON,
Assistant Geologist.

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Photo. C. G. Gibson.

Granite Rocks, Cardinia.

Photo. C. G. Gibson.

Rock Hole in Granite, Jumanuia.

Photo. C. G. Gibson.

View on Ponton River. N. from 102 M.P.

Photo. C. G. Gilson.

Granite Rocks, 5m. N. of Ponton River.

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Photo. C. G. Gibson.

Quartzite-capped Hill near Eudarie.

Photo. C. G. Gibson.

Eudarie Rock (Granite).

Photo. C. G. Gibson.

Gnamma Hole, Eudarie Rock.

Photo. C. G. Gilson.

Small Salt Lake 9m. N.N.W. from Bunninginia Rock.

Photo. C. G. Gibson.

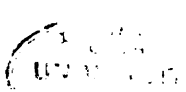
Sand Soak, Goddard's Creek.

Photo. C. G. Gibson.

Camels at small Rock Hole in Limestone.

Photo. C. G. Gibson.

Main Survey Party getting water at Rock Hole in Limestone near 243 M.P.



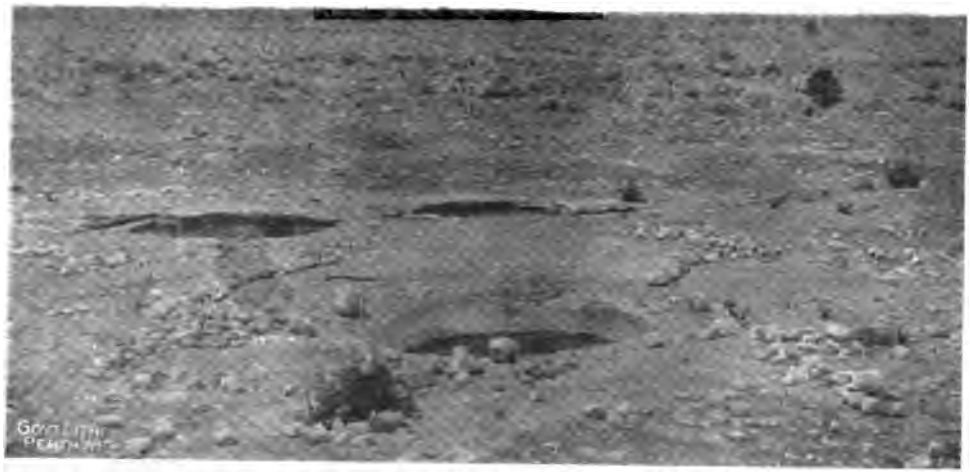


Photo. C. G. Gibson.

Rock Holes in Limestone near 220 M.P.

Photo. C. G. Gibson.

Limestone Cliffs near Twilight Cove.

Limestone Cliffs near Twilight Cove.

Photo. C. G. Gibson.

Photo. C. G. Gibson.

Limestone Cliffs near Twilight Cove.

Photo. C. G. Gibson.

Fresh water Spring at foot of Cliffs. Twilight Cove.

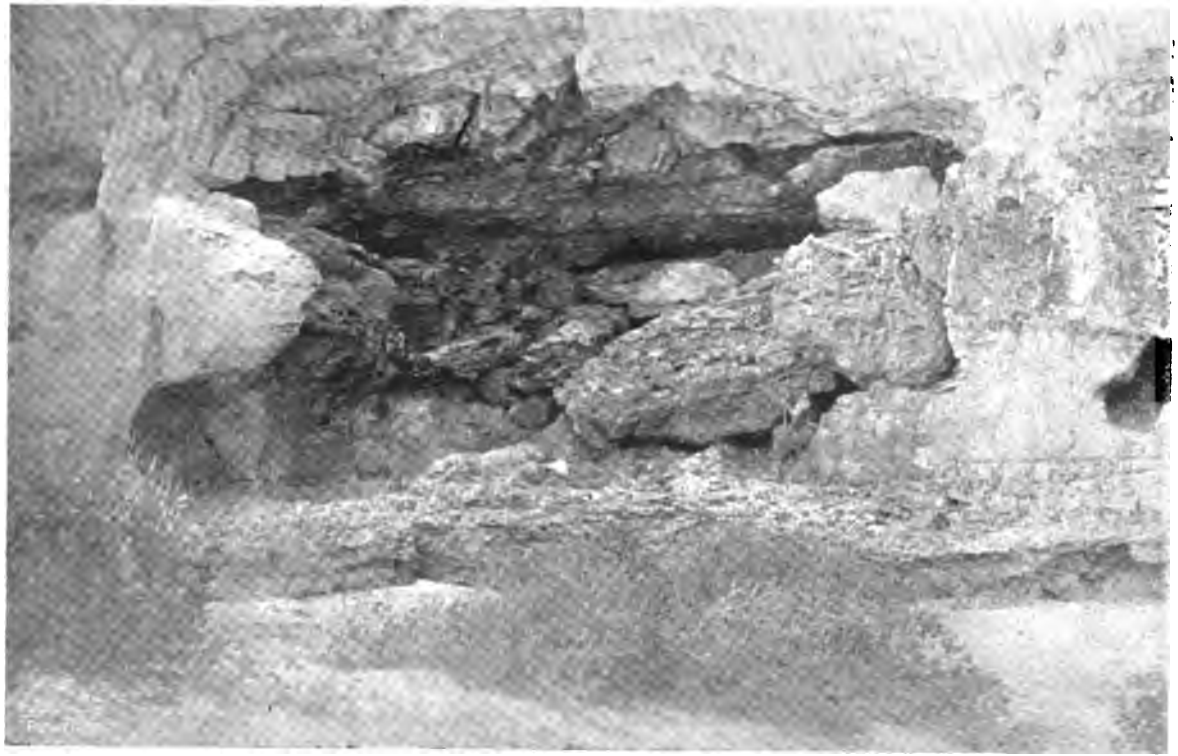


Photo. C. G. Gibson.

Water-worn Cave in Limestone Cliff, Twilight Cove.

Photo. C. G. Gibson.

Drifting Sand-hills, Eyre.

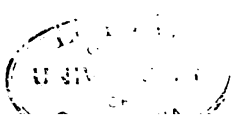


Photo. C. G. Gibson. Granite Rocks, Baliadonia.

Photo. C. G. Gibson.

North end of Lake Cowan.

Photo. C. G. Gibson.

Camels crossing the North portion of Lake Lefroy.

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CNTAL RAILWAY

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1910.

WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 38.

THE IRWIN RIVER COALFIELD,

AND THE ADJACENT DISTRICTS FROM

ARRINO TO NORTHAMPTON.

BY

W. D. CAMPBELL,
Assistant Geologist.

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Issued under the Authority of the Hon. W. C. Gregory, M.L.A., Minister for Mines.

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PREFATORY NOTE.

During the last 10 or 12 years a good deal of boring has been carried out in the Irwin River District with, *inter alia,* the object of defining the area over which the Coal Measures extend and their probable extension beneath the Mesozoic and Newer Rocks.

The following table gives a list of the various bores, and other cognate particulars:—

Name of Bore.	Depth in feet.	Remarks.
Dongara	2,111	Not bottomed.
Yardarino	1,607	Not bottomed.
Mingenew	994	Not bottomed.
Geraldton (Town)	420	Bottomed, granite.
Do. (Racecourse) ..	1,531	Not bottomed.
Mullewa (47¼m.)	1,418	Not bottomed.

Difficulties connected with the operations led to the abandonment of the latter before the base of the formation had been unequivocally reached. Geological evidence bearing upon the probable extent and nature of the Irwin River Coal-bearing rocks being incomplete, it was deemed necessary in the interests of the State that a more or less detailed examination of the district should be undertaken, such being absolutely necessary before any further boring operations could be carried out.

The ground embraced by Mr. Campbell's field work covers an area of about 2,000 square miles, and is depicted on the Geological Map which forms Plate I.

Mr. Campbell's field work, however, necessitated some attention being paid to the crystalline and metamorphic rocks, which formed the floor upon which the newer strata were laid down, hence a brief account of these is given in the opening portion of the report. This, accompanied by the geological maps, shows that these older beds extend over a considerable area and occupy the eastern portion of the district at the headwaters of the Greenough and

Irwin Rivers. These beds also occur in the valley of the Arrowsmith River, just to the west of Arrino, and occupy a narrow strip of country extending due north nearly as far as the mouth of Greenbrook, one of the tributaries of the Irwin. Another development of them occurs in the lower reaches of the Greenough River, where they form a huge island entirely surrounded by the Jurassic Beds. The most extensive area, however, is to be found in the valleys of the Chapman, Oakagee, and Bowes Rivers, where they rise to considerable elevations above the level of the sea, and extend northwards far beyond the area embraced by Mr. Campbell's work.

One of the most noticeable and perhaps the most important feature is the remarkably straight boundary line which limits the older rocks on the east, and is very suggestive of the junction being marked by a fault.

The older rocks consist largely of granite and gneiss, traversed by dykes of diabase, basalt, and norite, and lodes of lead and copper, in addition to quartz veins which may possibly be auriferous to a slight degree.

The gneisses seem to occur as broad, well-defined zones having an average north-west and south-east strike. In the Chapman River near Carney, the coarsely crystalline granite is brecciated and contains blocks of finely crystalline garnetiferous granite. This ancient crystalline complex is traversed in places by bands of hornblende schist which may be merely transmuted basic dykes.

Prior to the deposition of the Carboniferous and Newer Strata the crystalline complex appears to have been greatly eroded and weathered, forming an exceedingly irregular surface upon which they were ultimately laid down.

Resting upon these ancient crystalline rocks are a series of beds of as yet undetermined age, described by Mr. Campbell under the name of quartz-conglomerates, and submarine tuffs. These beds occupy, as is indicated on the geological sketch maps, a fairly considerable area of country. Representatives of this series are first met with near Moora, from whence they extend as a continuous strip, as yet undefined, northwards as far as Greenbrook, on the Irwin River, having been noticed and examined at Jingemia, near Watheroo, Coorow, Carnamah, Three Springs, and Arrino. To the east of this what are believed to be beds of the same series occur in the neighbourhood of Billeranga Hill and occupy the valley of the Greenough between Bindoo and Barraweelbarra Hills. Small outlying patches are met with in the headwaters of the Chapman and the Bowes Rivers, whilst an isolated exposure occurs in the 193¼ miles cutting on the Geraldton-Cue Railway Line. The beds forming the series consist of highly inclined sandstones, submarine tuffs, grits, and quartz conglomerates, all of which seem to have a prevailing dip to the eastward. No estimate however of the thickness of these beds is possible. It is these beds which carry the copper deposits of Arrino and Yandanooka.

The Carboniferous Rocks occupy a fairly large area in the valleys of the Lockier and Irwin Rivers, and the upper portion of Kockatea Creek, but the northern extension of the beds has not as yet been defined. The strata, which are fossiliferous, consist of shales, clays, sandstones, and limestones, together with occasional bands of ironstone. So far as Mr. Campbell's observations have been carried, it appears that the beds are arranged in a very broad anticlinal fold, the axis of which trends generally north and south. One very important feature in the series is the recognition of a glacial boulder bed, the debris of which strews the surface for a considerable distance. The boulders consist of a heterogeneous collection of granite, gneiss, quartzite, basic lavas, etc., many of them being beautifully glaciated. The debris of the boulder bed occurs more or less regularly along a general north-west direction over the whole area of the Coalfield, and appears to mark a very important geological horizon. The boulder bed, according to Mr. Campbell's observations, does not appear to lie exactly at the base of the Carboniferous Series as developed in this portion of the State, and is in all probability the southern extension of that occurring in the valleys of the Lyndon, Lyons, Gascoyne, and Wooramel Rivers, which are described in Bulletin 33.

Upon the denuded surfaces of all the preceding rocks the Jurassic strata were laid down, and occupy about two-thirds of the country examined. The beds consist largely of sandstones, clay shales, limestones, and here and there small patches of lignite. The beds are practically horizontal and have been very little disturbed from the position in which they were laid down. According to Mr. Campbell's estimates the Jurassic beds attain a thickness of at least 3,000 feet. The plant remains found in these beds seem to indicate an early Jurassic Age.

To the Jurassic beds succeed a series of limestones and arenaceous strata, referred by Mr. Campbell to the Tertiary. The basal beds of the Series are seen unconformably resting on the Jurassic rocks in the valley of the Hutt River, near Lynton. The Tertiary limestones and sandstones everywhere occupy a relatively narrow strip of country, which does not extend for any great distance inland from the coast, though in certain localities they rise to altitudes about 800 feet above the level of the sea. Very many picturesque caves occupy this formation, full details in connection with which are given by Mr. Campbell, their position being indicated on the maps.

In addition to these beds the coast is everywhere flanked by sandy and coralline limestones, as well as sand dunes, which latter often rise to 300 feet above the sea, though with one exception they are mostly confined to a strip about half a mile in width.

Certain interesting moraine-like lines of rock in the vicinity of Mt. Hill have been noted, described and photographed, and to these Mr. Campbell ascribes a glacial origin. The evidence, how-

ever, in favour of this is not by any means conclusive; the deposits, however, appear in many respects to resemble those taluses of stony debris which often form at the base of many escarpments.

Mr. Campbell, in addition, gives full details as to the diatomaceous earths, guanos, the salt deposits at Hutt Lagoon, and other economic products met with during his work.

A. GIBB MAITLAND,

GOVERNMENT GEOLOGIST.

Geological Survey Office,
Perth, 15th September, 1909.

THE IRWIN RIVER COALFIELD AND THE ADJACENT DISTRICTS FROM ARRINO TO NORTHAMPTON.

PREVIOUS OFFICIAL REPORTS.

In the Report of the Department of Mines for the year 1895. the following report by Mr. H. P. Woodward, then Government Geologist, appeared, accompanied by a sketch map, dated the 14th of January, 1896:—

THE IRWIN COALFIELD.

The Irwin Coalfield is situated upon what is generally known as the Upper Irwin, or, in other words, the area drained by the various eastern branches of the Irwin River.

This tract of country lies between 30 and 40 miles from the coast, and is extremely fertile. The soil for the most part consists of rich red loam or clay, which yields, year after year, fine crops, even when cultivated in the most primitive manner. The great drawback in this district is the scarcity of fresh water, and to this fact may be attributed the small amount of settlement that has taken place, for had fresh water been easily procurable there is not the least doubt but that it would have been long ago a large wheat producing district, since the land can be cheaply prepared for the plough, and as there are no rock outcrops anyone taking up land can cultivate the whole

Valley of the Greenbrook, two miles north of Mount Scratch.

Fig. 1.

of it. The soil of this area is of great depth, resulting as it does from the decomposition of the carboniferous shale beds; it more nearly resembles that of the agricultural districts of England than that generally met with in this Colony, which is, as a rule, of no great depth except in the gullies, and even there outcrops of rock are often met with. (Fig. 1.)

The carboniferous basin spreads out to the eastward, covering a fan-shaped area, which is surrounded on most sides by cliffs of horizontally bedded sandstone, about 200ft. in height, which form the edge of the sandy tableland, and it is at the base of these beds, where they rest directly, but generally uncomformably upon the shales, that springs break out at several places, which form the principal water supply of the district, since in most of the wells sunk brackish water has been met with, but where fresh water has been struck the supply proved generally to be too small to be of any great value.

Indications of coal were first reported to exist upon the Irwin River, by Gregory, in the year 1846, which report was a little later confirmed by the Geologist (Dr. Von Sommer), who stated that there were two seams 6ft. and 8ft. in thickness respectively, and it was upon this report that the Government declared a reserve of 10,000 acres. For over 30 years this important discovery was not investigated further: but, in the year 1879, the Legislative Council voted the sum of £100 in order to test the quality of the coal, with which object a shaft was sunk to a depth of 50ft., in which, although no coal was struck, the indications were considered promising. A little later the Government sent the Rev. Mr. C. G. Nicolay, M.A., who reported that, on account of the great quantity of water met with in sinking and the poor quality of the coal, the discovery was of no value.

The field was therefore abandoned until the year 1888, when Messrs. Bell and Eliot found some fragments of coal in the bed of the North Branch, which proved to be of a very fair quality. These they traced up to their source, which they found to be a seam of about 4ft. in thickness, into which they put a drive 150ft. down the dip, but although it improved both in size and quality it did not prove at the time to be of sufficient value to induce them to expend any more money upon its development. Another lower seam of smutty coal, about 2ft. in thickness, was also opened up, and about 10 tons raised, which proved to be of a rather better quality, but work was then discontinued owing to the breaking up of the Company. Some more seams were also opened up upon another branch, but they did not prove, at the time, of any value, on account of there being no local demand for coal, and also because the quality was not good enough for export.

The carboniferous area spreads out from Mingenew in an easterly direction, covering an area of about 200 square miles, its greatest length from north to south, from Badgeree Pool upon the North Branch to Mt. Scratch, being about 30 miles, whilst its greatest width from Mingenew to Narandagry, upon the Lockier River, is about 17 miles. To the north-west this area is bounded by the high sandy tableland which extends away to the northward as far as the Greenough River. The south is bounded for the most part by the low outcrops of metamorphic rock, which contains many copper lodes; to the eastward by the bold escarpment of crystalline rocks, flanked by horizontally bedded Tertiary sandstones, which often present towards the plains vertical cliff faces of as much as 200ft., particularly where streams have cut deep channels through them; whilst to the westward it is bounded by more high sandy plains which extend as far as the coast. Of these boundaries, that to the south and east may be taken as the definite edges of the Carboniferous formation, but that to the north and west only as provisional, since the sandstones which form the high sand plain in these directions are of a much more recent date, and may overlie extensions of the Carboniferous formation, and since we know that Carboniferous rocks outcrop in the river valleys further to the northward, it is highly probable that they are part of the same formation; and if this should prove to be the case, valuable coal deposits may be found beneath the high sand plains which lie between the Irwin, Greenough, and Murchison Rivers.

The Carboniferous formation consists of a series of beds of shale, sandstone, and limestone, the latter being rich in Lower Carboniferous marine fossils, but since these beds dip under the coal bearing series, it is probable that the latter may belong to the Upper Carboniferous period, but this has not yet been determined. The thickness of these formations exposed in cliff sections is about 300ft., but from trial bores, wells, etc., sunk on the plains further to the westward, we know that shale beds of great thickness underlie the fossiliferous limestones.

The coal measures seen in section consists of:—

	feet.
Yellow sandy shale, about	10
Coal	3 to 5
Sandy shale	10
Blue shale	10
Brown shale	20
Coaly shale	4
Yellow shale	15
Grit	6
Blue shale	4
Coal	2
Dark shale	20
Upper or coal bearing series	105

Here a break occurs, but as the Recent ferruginous sandstone formation, which caps all the cliff, descends and covers the passage beds, it is impossible to say what relationship the upper series bear to the lower, which latter consist of:—

	feet.
Mottled sandstone	20
Calcareous sandy shales	40
False-bedded sandstone	5
Shaly sandstone	5
Calcareous sandstones, often shaly (fossils) ..	30
Blue gypsum shales (fossils)	20
Blue shale	unknown
Thickness exposed	120

Mr. R. Etheridge, F.R.S., reports on a sample submitted to him:—"It is a dull, soft, impure, sooty coal, ignites quickly, and burns to a fine ash, giving out great heat. This sample, although impure, is not a lignite. It resembles 'Mother Coal,' bands of which often occur in the coal measure seams, interbedded between thick coals of the best quality.' It appears to me to have been taken from near the outcrop, or at a little depth from the air. No woody, earthy, or sedimentary matter occurs in this sample, and although far less valuable than Nos. 1 and 2, yet it is quite equal to much of the coal used on the North German railways, and is (although inferior) a true coal measure coal and not a lignite. No evidence of a ligneous structure could be observed under the microscope."

The fossils are all of characteristic Carboniferous age, and although there are no coal measure plants, there is no reason to doubt that the coal seams and associated limestone belong to one and the same age, *i.e.*, Carboniferous.

The coal itself occurs in thin seams mixed with coaly shale; it is dirty to the touch, and contains so much water that it falls to pieces on exposure to the atmosphere.

Two assays made in London gave the following results (No. 1 was by Mr. Harland, and No. 2 by Mr. Wingham), whilst No. 3 was made in Perth by the Government Assayer:—

	1	2	3
Water	17.04	12.4	15.63
Volatile matter ..	28.61	32.2	23.06
Fixed carbon ..	41.29	43.5	39.32
Ash	13.06	11.9	21.99
	100.00	100.0	100.00
Sulphur	..	0.83	Trace.

The large amount of ash may, in part, be due to extraneous earthy matter. The coal cannot be utilised for gas making, as it does not cake, and the coke formed, being in powder, is valueless; but the coal can be used for steam boilers and household purposes, and for those metallurgical operations in which a particularly high temperature is not required.

All these samples, it must be remembered, are of highly weathered coal, and were taken from or near the cliff face. If any samples were assayed from the end of the drive they were done privately for the Company, and the results are not obtainable, whilst at present the drive is full of water. When it is remembered, therefore, that it is only outcrop coal, we have every reason to predict that it will improve greatly when opened up further, and should prove to be a very similar coal to that being worked at the Collie.

The Midland Railway Company, upon whose concessions the Coalfield is, have put down several bore holes to test it, but most of this work has been done without system, whilst in the deepest bore, which is something like 500ft., they abandoned work just as they struck black shale. The known outcrops are almost upon the line of the proposed railway between Mingenew and Mullewa, and therefore will be of great value to the Murchison Goldfield, where the great scarcity of fuel is already being greatly felt. Therefore, although it is not a first-class coal, it should be able to hold its own against imported coal, when we consider the extra handling, shippage, carriage, duty, etc. We may therefore hope before long to see this long neglected field the centre of a thriving industry.

A belt of Carboniferous country, about 20 miles in width, extends from the Irwin River to the northward, crossing the Greenough, the Murchison, the Wooramel, the Gascoyne, the Lyons, and Minilya Rivers, then spreading out over the Henry, Ashburton, and Fortescue Rivers, and forming the great tableland at the head of the DeGrey. It is true that up to the present only carbonaceous shales have been found, and the fossils all belong to the Lower Carboniferous or even to the Devonian series, but when the enormous area over which these rocks extend is taken into consideration, and that they dip under the Mesozoic formation to the Westward, it is highly probable that true coal measures do exist further north than the Irwin; but this point can only be proved by boring, and this work should be started at once along the Cue-Geraldton railway where it crosses the sand plain to the westward of Mullewa.

Reports were made in 1901 and 1903 by Mr. A. Gibb Maitland, Government Geologist, on the exploratory boring operations then being made; these were published in the Annual Progress Reports of the Geological Survey for those years and will be referred to subsequently.

CRYSTALLINE ROCKS.

In addition to the position of the crystalline rocks in the district described by Mr. Woodward in the above report, there is an outlying range of granite extending from Arrino nearly to Mingenew, a distance of 20 miles (Plate I. and Fig. 3, also negative No 12). The highest points of the range are four miles south-west from Arrino Station (1,270ft.) and Mount Muggawa and Mulingara Hill, five and a half and thirteen miles northerly from the same point, each about 1,230ft. The granitic rocks of this range vary considerably in character: at Arrino there is a siliceous granite [**7587**], at Mount Muggawa there is a gneiss [**5240**], at M.L. 12. Arrino [**4912**], and at the hill east of the Yandanooka Homestead [**5235**] is garnetiferous granite, while farther north it becomes gneissic again and contains pegmatite dykes [**7659, 7660**], also a finer crystalline form [**7872**], which latter also forms the outlying mass of granite to the northward forming the Brockman Hills. The western boundary of the granite is mostly hidden by the sand-plains, but can be seen where valleys have cut through the overlying strata, more particularly at the Lockier and the North and South Branches of the Irwin River [**7704, 7705**]. Where the highly inclined sedimentary strata along the eastern boundary of the outlying granite range at Yandanooka can be seen to abut against the crystalline rocks, there is a margin of mica schist [**6658**], which is a result probably of pressure and chemical change of the granite.

Irwin River Falls.
Fig. 2.

The same causes have equally operated on the strata, transforming them into quartzites. It is also adjacent to this margin of the

granite that most of the copper ores occur as at Arrino and Mount Muggawa [**4897-4900, 4912-3**]. The lodes have mostly the same direction as the quartz reefs in their neighbourhood and shown on the map, viz., about 40 degrees west of north: they are short and underlay steeply to the west. These quartz reefs are few in number and are of small size.

The granite forming the main range of the inland plateau is met with about fifteen miles east of Mingenew, trending parallel with the coast line. It attains here a general elevation of about 1,400 feet and has a gneissic and porphyritic character, and there are occasional diorite dykes traversing it on a bearing a little east of north. Its boundary forms the Falls of the Irwin River, which are about 50ft. high, but at the Lockier River it is not so marked. (Fig. 2, Negative 345 [**7653/4, 7703/5, 7791, 7855/6, 8013, 8067**]; descriptions of these are given in the Brief Notes on the Irwin River Rocks, pp. 93-99.) There does not appear to be any general fault boundary of the granite, but the range presents work and rounded surfaces over which possibly an ice cap, or glaciers, descended into the sea where the saline clays, shales, and boulder beds were deposited.

Mount Misery.

Fig. 3.

In the Corynginia Gully the sandstones adjacent to the granite are faulted in various directions, which probably indicates that the gully had its origin along a fault line [**7793**] and possibly also a crushing of the sedimentary strata against the granite. Several quartz reefs, having widths of from 20 to 90 feet, can be seen crossing the Rothsay Road a few miles eastward of Ebano Spring, in directions nearly at right angles with each other, viz., 20 and 160 degrees; these have mostly a white and granulated character.

Specks of gold are reported to have been found about here by fencers, but no assays appear to have been made. The quartz reefs here are not attractive in regard to gold possibilities, having a barren appearance, which however may not be a true criterion [**7655, 7868**].

In the neighbourhood of Peterwangy Hill, 30 miles north-westerly from here, there is an extensive area of hornblendic gneiss and schist accompanied by quartz reefs; a little gold was found in the year 1868 on the eastern side of the hill in some shallow alluvial; the find, however, did not amount to more than "colours," but it occasioned the first gold rush in the State [**7707-9**].

Occasional fragments of antimony and plumbago are said to have been found in the Upper Irwin district, also some lodes containing lead ore, but no instances have come under notice during this survey.

The Granite Valley of the Greenough River.
Fig. 4.

Granite and gneiss appear again 6½ miles from the coast at the Greenough River, 47 miles due west from the Irwin River Falls already mentioned, and extend northwards with a general width of about 16 miles to the Murchison district (Figs. 4 and 5), but are covered in places with outliers of the sandstones that at one time covered its whole surface but which have since been denuded to a large extent [**3941, 3946, 3949, 3685** and **25, 198/9, 4847, 8824**]. In this area, which may be described as the Northampton district, the granite and gneiss are mostly garnetiferous and distinct from the granite of the country from Ebano Spring to Kockatea Spring previously alluded to, which does not contain accessory minerals and may possibly be of a different geological age. The crystals of garnet are mostly small, but in some instances they attain a diameter of half an inch [**8685**], and are always full of fractures due

probably to the pressure of the crystallising quartz and felspar [**10. 34. 176 8, 3022, 3170. 3946, 4050, 4787/8, 4868, 4897, 8067, 8809, 8813, 8819, 8826**]. The denudation of this large extent of garnet rock has caused the sand of the sea beach from the Murchison River to Geraldton to be garnetiferous [**4793/4**].

Sandplain five miles east of Northampton.

Fig. 5.

Tourmaline is a frequent accessory mineral in the Northampton district forming occasionally tourmaline granite [**22**]; the crystals are often large and well formed [**18, 19, 197, 205, 1605, 4016, 4803**].

Graphite has been found in several places as at Loc. 2674, about 1½ miles west of Norman's Well, and at the Waneranooka Mine, and stray pieces have been picked up at Loc. 48/1982 on the east branch of the Chapman River. It has not been found, however, in marketable quantities [**20, 4057, 6293, 6639, 8851**].

Micaceous varieties of granite are not frequent and are mostly associated with pegmatite veins, the mica being chiefly muscovite. At Loc. 3078 near Nonga Hill, mica crystals over four inches diameter are obtainable. Two belts of mica schist occur at Loc. 334 crossing the lode of the Wheal Fortune Mine, Northampton [**23, 196, 6357, 8613, 8852**].

There is on the other hand a frequent absence of mica, thus forming aplite and the varieties of this rock known as pegmatite and graphic granite [**21, 198/9, 4057/8, 4785/6, 4847, 6356, 8796**].

Porphyritic structure can be observed occasionally as at the Wheal Ellen mine [**177**] with orthoclase felspar [**21, 31, 194/5**]. A quartz felspar porphyry was noticed at Tibraddon [**6661**]; this specimen was stated in error in Bulletin No. 26, p. 36, to be a diorite.

The gneissose variety apparently occurs in broad zones in the granite, and these again have well-defined belts of schisted gneiss evidently denoting lines of stress [**3946, 8809, 8819**]. A zone of this character is largely prevalent along the western margin near the coast, and can be seen at Loc. 2249, Oakagee River [**8857**], and at Loc. 1467, Oakabeila River, where it is greatly contorted. At the Bowes River, Loc. 2777, about one mile north-easterly from Willow Gully Homestead, it forms a prominent ridge. Another zone occurs at two miles north-east of Fossil Hill, Narra Tarra, and at the Yanget Hill near the eastern margin of the granite [**8794**]. Several zones of a similar character designated "quartz schists" (aplite gneiss) and "schisted zones of mica schist" are indicated on the Northampton Geological Map, and they almost all have a north-westerly and south-easterly direction.

A brecciated granite evidently denoting some upheaval during the solidification of the mass occurs at the road crossing of the Chapman River at Loc. 2402 near Carney. Here there is a coarsely crystalline granite enclosing blocks ranging up to 18 inches in diameter composed of a finely crystalline garnet granite, giving it almost an orbicular appearance [**8815/6**].

The hornblende schist and diabase of Peterwangy Hill may also represent another crush zone of the granitic rocks, which may be represented again 24 miles south-easterly at the line of similar hills crossing Loc. 3418, seven miles east of Yungarlo Well [**7707/9**]. These hills continue in a south-easterly direction towards Loc. 3084 where there is a lava outcrop trending nearly east and west. The strata adjacent, composed of sandstones and mudstones, are greatly silicified [**7858/61**].

An interesting group of dykes occurs at the east branch of the Chapman River, north of Beatenally Hill, and includes basalt, norite, and diabase [**8808/11**]. Norite also occurs two miles south-east of Norman's Well, about 16 miles northerly from the other locality. The large number of diorite dykes in the Northampton area is very noticeable, these all trend about N.N.E. and S.W. and their occurrence has doubtless an intimate connection with the deposition of lodes of copper, lead, and zinc in their vicinity.

Lead and copper were discovered near the present site of Northampton as early as 1842, and in 1848 important deposits of lead and copper were found on the Murchison River (Plate II.), and the land in which they occurred was sold in the following year by auction at £1 per acre and the Geraldine mine was then opened. The minerals were continued to be sold with the land until the year 1898, by which time most of the finds of ore had passed into private hands without any obligation for the working of the ore.

The above remarks are taken from a typographical copy of a most able account of "The Development of Mining Law in W.A." by Mr. A. C. Veatch, Geologist, U.S. Geological Survey, in the possession of the Department.

This private ownership has not had a salutary effect upon the development of the mining industry, and the Mining Act of 1904 has been inoperative in regard to the privately owned land. The Mining on Private Property Act of 1st January, 1899, has not been found to be of much assistance towards making accessible these minerals. The low market value of ore has also discouraged development work, and there is practically no mine being worked in the district at the present time.

Most of the Northampton mines were described in 1903 by Mr. H. P. Woodward and Mr. John Provis, and Mr. A. Gibb Maitland in Bulletin No. 9 of the Geological Survey, which was accompanied by a Geological Map on a scale of half a mile to an inch, by the latter gentleman. The following corrections however require to be mentioned:—Bulletin No. 9, p. 14: In description of Gray's Lead Mine, for block 29 read 470; p. 18, for Wheal Mary Lead Mine read Wheal May Lead Mine; p. 20, South Geraldine Lead Mine, for Loc 9 read M.L. 109; p. 21, for Two Sisters read Three Sisters.

Mr. A. Montgomery, the State Mining Engineer, in his report on the Northampton Mineral Field of 3rd March, 1908, has also described most of the mines.

The following notes are additional to the already published descriptions of the mines:—

NORTHAMPTON LODES.

Locs. 2342 and 2346.—Lead. 2 miles west of Northampton.

Loc. 2755, Burnt Iron Copper Mine.—Copper. One shaft, no distinct lode found.

M.L. 1, Kirton's.—Lead. Strike 30 to 35, dip 75 E.

M.L. 6, Uga.—Lead. Dip W., lode 8ft. wide, shoot dips N., worked to 70ft. depth.

M.L. 7, Nooka.—Lead. Width of lode 2-8ft., water stopped work.

M.L. 9, Alpha.—Copper. Strike 15, dip W., lode about 2ft. wide.

M.L. 33, Wheal Beta.—Copper and Lead. 1½ miles N. of Northampton; several shafts, some stoping done.

M.L. 38, Victoria.—Copper. Strike 15, dip W., lode about 2ft. wide.

M.L. 51, Alma.—Lead. Lode width 2½ft., good galena bunches.

M.L. 76, Yiappa.—Lead. Lode width about 3ft., with 6in. to 18in. rich galena, over 800 tons raised.

M.L. 77, Lauder's.—Lead and copper. Strike 178, dip 75 E., lode 3ft. wide, one shaft 30ft., 15 tons raised, 3024.

M.L. 78, Geraldton.—Lead. At north boundary of Loc. 118, Narra Tarra.

M.L. 88, Sunny Corner.—Lead. South of Nanga Hill, 2 parallel lodes, 2 pits only.

M.L. 89, Wheal Margaret.—Copper. Strike 23, dip 85 W.

M.L. 91, Jack's Well.—Copper. 2 miles south of Jiberno Spring.

M.L. 103, Cornstalk.—Lead. 1½ miles N.E. of Isseka Siding.

MURCHISON LODES (see Plate II.).

Loc. 4, North Geraldine.—Lead. Dip 73 N.W., stoping done to about 30ft. depth.

Loc. 5.—Lead. Lode parallel to Lady Florence.

Loc. 6.—Copper and Lead. Dip 70 N.W., situated 1 mile south of Loc. 6, one shaft sunk.

Loc. 10.—Copper and lead. On west side of a diorite dyke, no work done.

M.L. 44, Reynold's Mine.—Lead. Strike about S.E. and N.W.

M.L. 61, Welcome.—Copper and lead. ¼ mile S.W. of Loc. 10, on a continuation of that lode.

M.L. 80, Ethel Maude.—Lead. Distinct but parallel to lode in Loc. 4.

M.L. 95, Hennings.—Lead. Strike 180, workings to 25ft. deep; stated to have contained silver up to 25ozs. per ton.

M.L. 104, Wheal Mary.—Lead.

M.L. 106, Wheal Thomas.—Lead and Copper.

M.L. 117, Nooka.—Strike 205, dip 75 W., lode 2-8ft. wide, worked to 90ft.

GENERAL NOTES.

Loc. 1, Geraldine Lead Mine.—The lode has a N.E. and S.W. strike and is in the bed of the river, which is subject to frequent floods, and rises occasionally to a height of 30ft.; in summer it is dry.

Loc. 2, Lady Florence.—Strike approximates to the last. Dip about 80 N.W.; stoped to about 70ft. depth.

Loc. 1472, Baddera.—There is a new shaft 160ft. deep with a drive towards, but not so far as, the lode. Strike 222, dip 75 N.W., shoot dips south. This is the most promising lead mine in the district.

Loc. 314, Bandy's Yanganooka Copper Mine.—Continuation of the west lode of the Yanganooka mine; shaft about 30ft. deep, showing grey ore.

Loc. 335, Woomboarra.—One mile south of Martin's Spring mine; strike 240, dip 70 E.

Loc. 436, Rhy's Lead Mine.—Continuation of lode in Loc. 334; underlay 75 E.

Loc. 21, near Isseka Siding.—Several shafts have been sunk 20ft. to 30ft. on a copper lode.

Loc. 832, McGuire's.—Several shafts have been sunk on each of the two lodes and stoping has been done on both.

Loc. 470, The Saxon Lead Mine.—Strike of lode 157, dip 63 W.

Loc. 4, White Peak.—Lode strikes 110; two shafts, now caved in.

Loc. 833, Narra Tarra Lead Mine. Recent work has been done on the eastern lode; machinery of latter in working order. The two lodes here dip towards each other.

Loc. 1146.—The ore shoot dips south, lode 12-15ft. width, containing leaders of lead and 6ft. of solid lead ore.

The area occupied by the crystalline rocks in this district was indicated on a map of "The Mineral Leases of the Northampton District" on a scale of $^1_2$ inch to a mile, published by the Mines Department on 12th December, 1901, No. 129. A Geological Map and section of a portion of the Greenough River District appeared as Plates V. and VI. of Bulletin No. 26, with a brief description on pp. 34-6.

It is evident on examination that the surface of the granite was greatly eroded and weathered prior to the deposition of the sandstones, this can be well seen in the Greenough valley around Minnenooka and Tibraddon (Figs. 4 and 7, neg. 254/5, 368, 462), also around Newmarracarra and at the deep railway cutting east of No. 1 tank, 19¾ miles (Plate IV. and Fig. 6), also at Fossil Hill, Narra Tarra, which has a patch of sandstone left on

the top and down stream side of the old granite hill. The name Fossil Hill has been evidently given by someone who mistook ironstone concretions for fossils.

The frequent presence of slickensides in the kaolin of the high level ground as at Loc. 2851, east of McGuire's Siding [**8691**] and at Loc. 1918, south-east end of Georgina road, Greenough 8069, also

Cue Railway Cutting at 19¾ miles.
Fig. 6.

shows that before the granite surface was covered by superincumbent strata, the granite was kaolinised. The slickenside character being due to pressure.

QUARTZ CONGLOMERATES AND SUBMARINE TUFF. AGE UNDETERMINED.

On the east side of the outlying granite range at Arrino and Yandanooka there are a series of sandstones, submarine tuffs, grits,

Granite underlying Jurassic Beds.

Fig. 7.

and quartz conglomerates that have an easterly dip ranging up to 65deg.; they vary considerably in the condition of solidification, induration and metamorphism. The quartz conglomerates and in-

Quartz Conglomerate, N.E. of Mount Misery, Yandanooka.

Fig. 8.

See negatives 14 and 375 [**4903/7, 5236, 5242, 7580, 7585**]. These tuffs apparently represent sedimentary volcanic ash of a basic or felspathic nature, and they merge in places into a volcanic agglomerate.

The following is an analysis of a typical sample of this tuff by Mr. E. S. Simpson:—

Reg. No. **6360.**	per cent.
Silica, SiO_2	67·56
Titanium oxide, TiO_2	·75
Carbon dioxide, CO_2	3·37
Phosphoric oxide, P_2O_5	·71
Water, H_2O (combined)	1·56
Soda, Na_2O	1·72
Potash, K_2O	2·39
Lime, CaO	5·75
Magnesia, MgO	2·48
Manganese oxide, MnO	·25
Iron protoxide, FeO	·91
Iron peroxide, Fe_2O_3	3·07
Alumina, Al_2O_3	9·27
Pyrites, FeS_2 Fe	·04
S_2	·05
Water, H_2O (hyg.)	·53
	100·41
Specific Gravity	2·65

This series probably appears again at the deep cutting of the No. 1 tank on the Cue Railway at 19¾ miles. The base of the section is decomposed gneiss having an eroded surface on which is a fine-grained soft sandstone of the tint of burnt umber that bears some outward resemblance to the volcanic tuffs of Arrino. The upper surface of this sandstone is eroded, and through both the granite and sandstone a fault passes, but it does not penetrate the superincumbent fossiliferous limestone and ferruginous beds of Jurassic age [**8804-6**] Fig. 6 and Plate IV. Patches of this old sandstone probably occur throughout the 23 miles northerly to Norman's Well where it is greatly silicified and rests on granite; both are penetrated by a galena lode [**8820-2, 8828-31, 8868-70**]. Although the tuffs are penetrated by lodes there have not been any instance where diorite or other dykes have been noticed in them of the quartz conglomerates.

Veins of copper ore have been found to occur both in the granite and gneiss and in these tuffs and sandstones. Prospecting and mining operations have been in progress here for short periods since about the year 1868, which has caused some attention to be given to the geology of the district as embodied in the Report of the Geological Survey for the year 1903, pp. 13 and 14. [**4901, 4911, 6360, 7343, 7580, 7582/4, 7586, 7594/5, 7589, 7590, 7649, 8078/9, 8080/1.**]

Mineralised country also exists towards Rothsay, about 40 miles east of Mingenew, for the Land Inspector showed the writer some samples of copper ore that he had brought from that district.

Mr. Camm, Government Surveyor, has also shown to the writer a sample of a magnetic iron lode which he states covers a large hill about 30 miles east of Carnamah, evidently on the same mineral belt.

Eastward from the main line of granite at Ebano Spring the elevation of that range or ramp is maintained and the aspect of the country becomes undulating with occasional hills ranging up to 1,700 feet in elevation. It is composed of a series of indurated sandstones, etc., which can be seen at the Billeranga Hill, 30 miles south-easterly from Mingenew. These rocks are there accompanied by diorite dykes, quartz reefs and volcanic rocks (amygdaloid) [**7858 9, 7860 5, 7875 7.**] The strata all dip at a high angle to the east and have been greatly silicified by chalcedonic infiltrations in the proximity of the volcanic rocks besides having frequent surface alterations, designated quartzite cappings, and in other places having concretionary ironstone gravel and laterite coverings.

The strata here exhibit both surface silicification and massive chalcedonic alterations of sandstones and claystones, these are no doubt the rocks from which have been derived the large blocks ranging up to nine or more feet long that can be seen scattered on the spurs of the escarpments and in the old high level gravels near De Burgh Spring and over the adjacent valleys at Greenbrook and Irwin River [**7788/90, 7844/50**]. The country further south to Billeranga Hill is composed of sandstones and flaggy sandstones dipping east with surface silicification [**7862-3, 7875-8**].

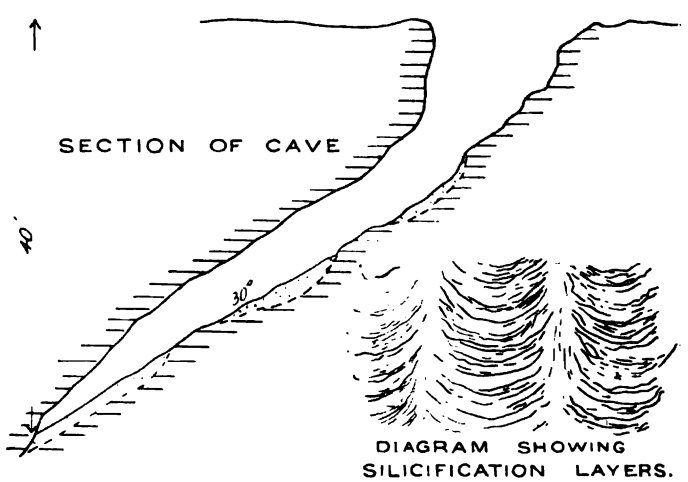
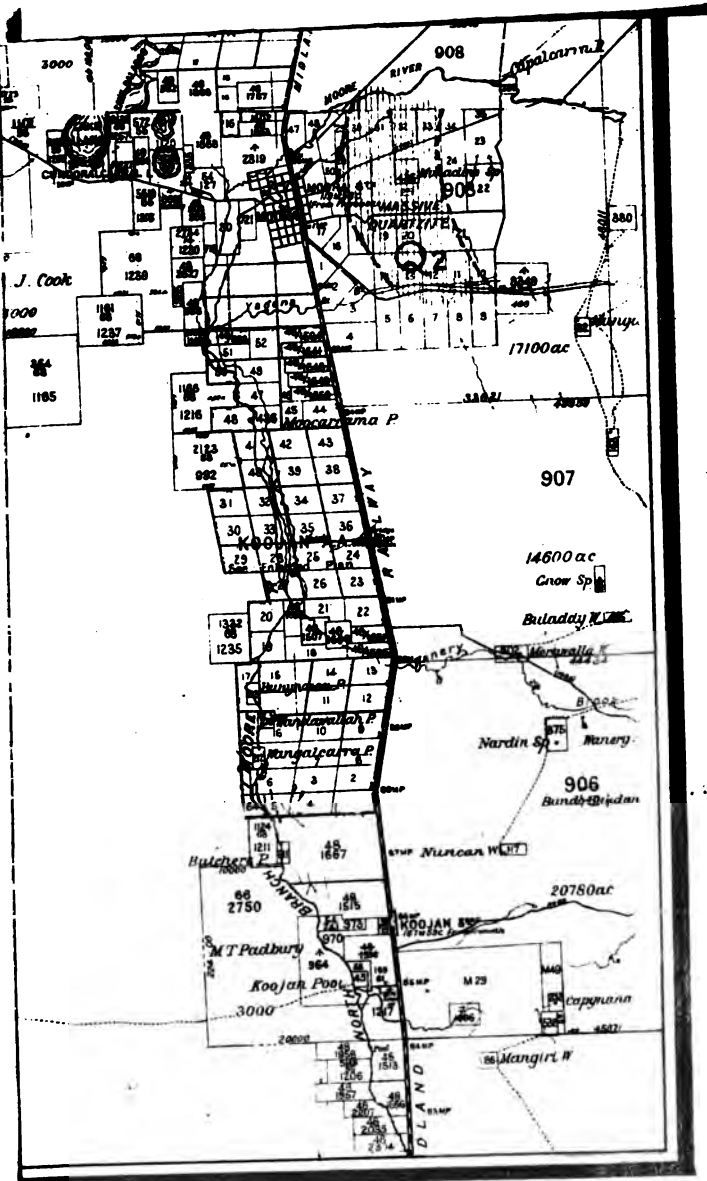


Fig. 10.

Southwards from here the survey has not been continuous but the same series apparently occurs at Coorow, about 40 miles south-



H.J Pether, Government Lithographer, Perth, W.A

degrees, whilst the bearing of the outcrop of the lode was 150 degrees, the latter underlying apparently 60 deg. to the west: this

s apparently occurs at Coorow, about 40 miles south-

easterly, associated with diorite dykes and there is an interesting fissure cavern about four miles south-west from the railway station; the inspection of this was the object of the writer's visit. It occurs in sandstone which is much silicified down to at least 40ft. vertical depth from the surface, which is as far as the cavern extends. The character of the alteration is the formation of thin sheets or filaments of chalcedony deposited in festoon-shaped order between vertical walls of the same material, from 6 to 12 inches apart, the interstices being composed of loose fine sand and sandstone. The diagrams below represent a sketch section of the cave and the appearance of the silicification [8010-2] Fig. 10.

At Watheroo, about 26 miles farther south, the range in which the large cave Jingemia occurs, containing guano deposits, has been described by Mr. H. P. Woodward as quartzite, which probably belongs to the same series.

Twenty-six miles farther south again there are massive quartzite hills, which are one to two miles eastward of Moora which are also probably of the same series. [6992-3] Plate III.

MINING AT ARRINO AND YANDANOOKA.

The first trial shafts were sunk at the water course near the railway station at Arrino, and at Mount Muggawa, about the year 1868 by an English Company, and from the first-named locality several tons of ore are said to have been obtained from a 20ft. shaft on the south side of the watercourse. A main shaft which was sunk in the watercourse to a depth of 80ft. did not cut the lode and appears to have reached the gneiss. The ore raised was shipped in a coasting vessel, the "Emily," in charge of Captain Harford; this vessel was unfortunately wrecked off the Moore River and the consignment lost. Several years after the abandonment of the ground a local company worked it and a new shaft was sunk south of the old workings but, although 40 tons of good ore appear to have been obtained, the mine was abandoned.

A brief reference was made to the lodes in this district by Mr. H. P. Woodward, in an account of the Principal Mining Districts of the State, which was printed as an Appendix to the Catalogue of Exhibits at the Inter-Colonial Exhibition of Mining and Metallurgy held in London, 1890, p. 24, and also on p. 126 of the Mining Handbook of W.A., 2nd edition, printed in 1895.

About the year 1897 this ground was again taken up and about 18 tons of stone raised and Mr. Woodward reporting upon the mine, stated that the lode was a mass of decomposed schist through which rich bunches and veins of green carbonate of copper are met with, the strike being 35deg. west of north and the dip west.

In a report by myself in 1903, the strike of the sandstone immediately to the west of the northern shaft was stated to be 163 degrees whilst the bearing of the outcrop of the lode was 155 degrees, the latter underlying apparently 60 deg. to the west; this

is seen also in the old shaft on the south bank, but a crosscut west from the shaft at 45ft. depth failed to reach the lode opened out at the north shaft. About 6 tons of ore were raised about this time from the mine by Mr. C. C. Cheyne, who had then taken it up.

Table showing the Yield of the Arrino Mine as officially reported.

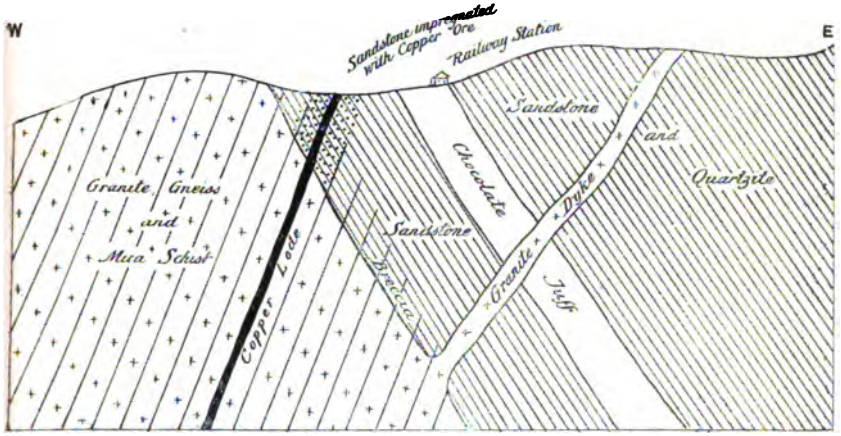
Year.	Name and Number of Lease.	Ore Crushed.	Value.
		Tons.	£
1901	Arrino, M.Ls. 3, 4 (subsequently M.L. 12)	25·00	300
	Lady Bertha, M.L. 7	3·00	27
	Wheal Dodd, M.L. 5	10·50	80
	Total	38·50	407

At Mount Muggawa the principal workings have been along a quartzose lode line outcropping in gneiss and mica schist about 1½ miles south-east of the Mount and trending about 30 degrees west of north. About the years 1868 to 1870 five underlay shafts were sunk by the English Company already mentioned, on the east side of the lode, which dips steeply to the eastward in the surface workings, but Mr. Woodward reported in 1897 that "the sixth was sunk vertically to a considerable depth upon its eastern side and did not cut it although a crosscut is said to have been driven towards it, showing that the lode either goes down almost vertically or else has turned over and dips to the westward; therefore it would be necessary to extend the crosscut further." The width of the lode is about 2ft. 6in., and a good many tons of ore were raised and shipped at Port Dongara, but of the actual quantity there is no record. The water in the main shaft is fresh and there is also a permanent soak of good water a little north of the mine on the reserve.

In the year 1903 copper ore was found about two miles south of Arrino Spring and 19 leases were applied for in the neighbourhood, but most of these were soon after abandoned. The writer reported on the find that "Baxter's mine in the west corner of Loc. 342" is probably about five chains east of the granite. Here two shafts have been sunk and an opencut at the northernmost one; both are about 60ft. deep. The strike of the sandstone is 15 degrees and the dip 58 degrees to east with cross faces dipping 70 degrees to west. At the new main shaft, 82ft. distant south-easterly from the last, the depth is 41ft., at which level a crosscut is being put in, the sandstone showing staining of carbonate of copper. This passed through a lode where a bunch of black sulphide of copper was met with, the bearing of the lode being 150 degrees and underlay 60 degrees to west."

Since that date the workings have been chiefly confined to a large opencut a few chains south-west of this, about 12ft. deep, where quite a stockwork of veins was met with. About 600 tons were raised and sent away from here by the Arrino Proprietary Copper Mining Company, but since 1906 the mine has been idle. [**4909, 4910/8, 5241, 5243.**]

The following diagram is a sketch section by Mr. E. S. Simpson showing the mode of occurrence of the lode at M.L. 4. It appeared on p. 13 of the Annual Progress Report of the Geological Survey for the year 1903; this report also contains two geological sketch maps of this mineral belt.



SECTION SHEWING OCCURRENCE OF COPPER ORE IN M L 4 MONEY MIA, ARRINO.
After E. S. Simpson

Fig. 11.

At the end of 1905 a strip of land ¾ mile wide along the boundary of the granite here for five miles southerly from the Arrino township was excluded from conditional purchase in order to facilitate mining operations.

Several shafts have been sunk between Mounts Muggawa and Misery at copper indications in chocolate-coloured tuff sandstone and agglomerate but without much result [**4897/9, 4900, 5239**].

In the year 1907 a copper-bearing vein was found in the north-western corner of Mr. C. Campbell's selection 4441 about a mile south-easterly from Mount Misery, in chocolate tuff, and at the time of my visit in August of that year, a shaft 52ft. deep had been put down on a crush formation 2ft. 6in. in width dipping 70 degrees to the south-west and trending north and south, in which were veins of ore, some being black sulphide of copper, 7½ tons of which had been raised and sent to Port Pirie, valued at £96. A sample obtained from here by Mr. C. G. Gibson, Assistant Geologist, was assayed at the Departmental laboratory and gave a result of Copper

33.16 per cent., Gold 21 grains per ton, Silver 16 dwts. 7 grains per ton. This rich pocket however was but a small one [**7342/4**].

About 1½ miles north of "Granite" hill at Yandanooka, a shaft was sunk in volcanic agglomerate where some green carbonate of copper occurred but no defined lode was found [**8078/9, 8080/1**].

Nearly four miles north from here, in the south-west corner of Loc. 1965, a copper vein was found by Mr. Beaton when excavating the tank and some of the ore was shown by him to Mr. Kellett, a geologist employed at the time by the Midland Railway Company, who is reported to have thought highly of it, but no further search was made, and the spot is now occupied by the water of the tank [**7649, 7650**]. Other copper indications appear to have been found about 1½ miles farther north, and a small pit was sunk on the spot many years ago.

At Mount Scratch, in Loc. 358, a shaft was sunk in the tuff, where green malachite and particles of native copper had been found; two other shafts were also sunk about a mile south-easterly from there near the north-east corner of M328, and three others about 1½ miles northerly, the stone raised showing veinlets of carbonate of copper but none of payable character; all these shafts were inaccessible at the time of this survey. The strata incline to the east at an angle of 60 degrees with a strike a little west of north. (Fig. 9, negatives 330, 331 [**7582, 7589, 7595**], Plate V., Cross-section 11.).

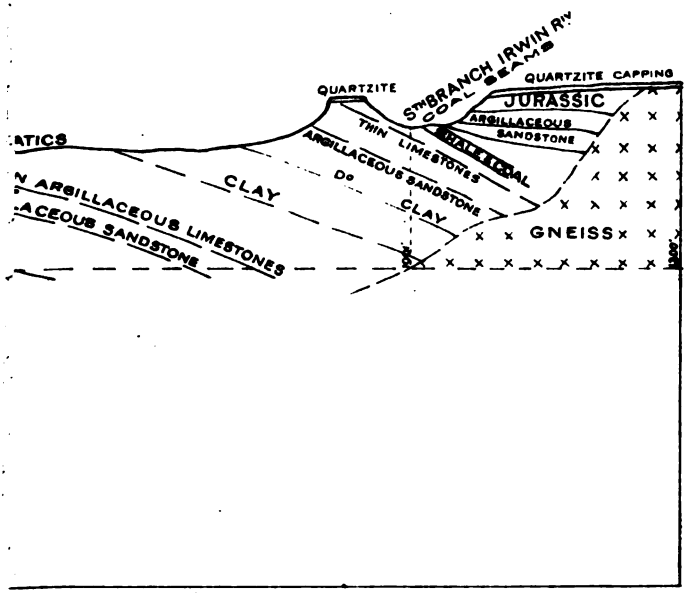
Clay Hills near Gnoolowa Hill, Irwin River.

Fig. 12.

CARBONIFEROUS AND PERMO-CARBONIFEROUS STRATA.

The Carboniferous and Permo-Carboniferous strata of the Greenbrook, Lockier, and Irwin River valleys present an uninter-

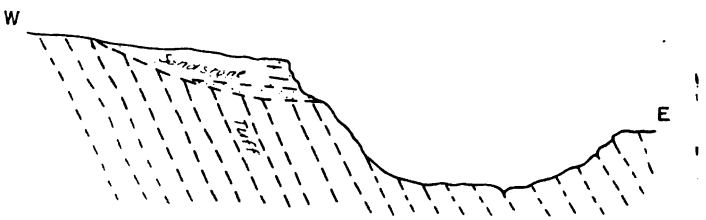
BULLETIN Nº 38 PLATE V.



Hon. H. Gregory M. L. A.
Minister for Mines

H. J. Pether, Government Lithographer, Perth, W.A.

rupted series of shale, clays, and sandstones, with occasional limestone and ironstone bands and silicified cappings. The shales and clays form chiefly the lower and middle portions, and argillaceous sandstones the upper portion of the series. The main body of the strata is very slightly indurated, abutting on its eastern side against gneiss and granite and on the south upon the highly inclined tuffaceous sandstones and metamorphic standstones or quartzites of Yandanooka and Mount Scratch; their unconformability can be seen near the north-east corner of Loc. M328 on the west side of the track.



SECTION ON LOC. 328

Fig. 13.

To the westward the Carboniferous beds extend nearly to Depot Hill and Mingenew; at 1½ miles east of the latter there are ferruginous sandstone hills containing Permo-Carboniferous fossils, clays, and sandstones similar to those of the Greenbrook, also they flank the west side of the granite and metamorphic hills to the south. The saline blue clays which appear in the bed of the Irwin River near the Mondara Spring, nearly 20 miles to the south-west, may possibly be of this age also. The whole series have mostly a marine or estuarine character, for even the carbonaceous seams are associated with saline shales. The higher ferruginous sandhills from Mingenew to Mt. Hill are apparently of Jurassic age, containing well preserved fossils, probably *Otozamites* and wood [**7676, 7722, 8017 9, 8104**].

The general structure of the district will be seen by a reference to the cross-sections (Plates V. and VI.) which show that there is a very flat anticlinal bend of the strata north-westerly from the line of granite hills at Yandanooka, and the general underlay on the east side of this axis is about 3 or 4 degrees and 2 degrees on the west side.

In the year 1903 a bore was put down for the Irwin River Coal Prospecting Syndicate by Mr. Atkinson about ¾ mile south-east of Mingenew to a depth of 913ft., but the result being indefinite it was

supplemented by a second bore by the Government to a depth of 736ft., when the work was stopped; both were in loose sandy strata. (See Annual Progress Report of the Geological Survey, 1903, p. 20.)

BORE No. 2, MINGENEW.

Nature of Strata.	Depth from which sample was taken, in feet.
Grey clay shale	78
Grey clay shale	126
Hard sandstone	130
White clay shale	207
Fine grey clay shale	228
Fine grey clay shale	290
Grey clay shale	380
Fine white clay shale	386
Hard sandstone	390
Fine white clay shale	400
Hard coarse sandstone	420
Fine white clay shale	435
Grey clay shale	500
Grey clay shale	548
Grey clay shale	578
Grey sandy shale	640
Grey clay shale	675
Grey clay shale	700
Grey clay shale with undeterminable plant remains	736

The position of this bore is on the west side of the above-mentioned axis, as is also the Depot Hill bore put down in 1902 for the Depot Hill Coal Mining and Prospecting Company by Mr. Hindley. The white and grey shales occur here also [**6695/6**]. The strata pierced (see Annual Progress Report of the Geological Survey for the year 1903, p. 17) was as follows:—

Sandstone	65ft.
Shale	6ft.
Sandstone	89ft.
	160ft.

The two sites are about 8½ miles apart and are probably in the same stratigraphical horizon. Occasionally enclosures of bituminous material (lignite) occur in the argillaceous sandstones of the Irwin River valley northwards, but they are not coal beds [**6689, 6690 1**].

A bore was put down about the year 1890 by the Midland Company on the east side of Greenbrook, on the advice of Mr. Kellett, about 10 chains south of the northern boundary of Block 1929 to a depth of 500ft. in clays and sandstone, and was abandoned just as they struck black shale, but neither coal nor water was reached.

A bore was put down at Dongara in the year 1900 by the Government for the purpose of determining the western margin of these

coal measures; a depth of 2,111ft. was reached, which was the limit of the capacity of the boring plant used, and no definite result was obtained as the strata passed through from 140ft. downwards appear to belong to the Jurassic series.

An analysis of a 4in. carbonaceous seam occurring at 265 feet carried out in the Departmental laboratory showed its composition to be in parts per hundred:—

Moisture	13.13
Volatile Hydrocarbon	29.47
Fixed Carbon	49.40
Ash	8.00

Another bore was put down the following year at Yardarino which was stopped at a depth of 1,670ft. through the tools being lost in the hole; neither bores gave any definite result as the Government Geologist considered that neither appeared to have reached the coal measures. (See Progress Report of the Geological Survey for the year 1901, pp. 13 and 14, and Bulletin No. 4, pp. 105 and 106, also Report of the Public Works Department, June, 1906, p. 34.)

In the year 1895 Mr. H. P. Woodward investigated the Carboniferous areas in the Upper Irwin and to the northward thereof, and found Carboniferous fossils on the Greenough River between the Kockatea and Wooderarrung watercourses (see Report of the Department of Mines for 1895 and part of 1896, p. 21); the results of his observations are embodied in the sketch map indicating the probable extent of the Carboniferous beds in that district, which accompanies the Annual Progress Report of the Geological Survey for the year 1903, p. 18. The conclusion from these data was that the Carboniferous beds extend northwards from the Irwin River across the Greenough valley under the overlying strata of later date.

In the year 1904 the Government made arrangements with the Diamond Drilling Company to put down a deep bore at the 47½ miles post on the Cue Railway, in order to endeavour to test both the possible existence of the coal measures and also to obtain a supply of water for locomotives, and a depth of 1,418ft. was reached, but it had to be abandoned in the following year before the base of the strata intersected had been reached, owing to difficulties in the boring. (See General Section in Bulletin 26, Plate VI.)

The following is a section of the strata pierced in this bore hole:—

	Feet below surface.
Sandstone and grit	0— 405
Light grey mudstones and bands of fine sandstone ..	405— 600
Pebble grits, ferruginous sandstones, fine sandstones, grits, shales, pyrites, and fine sandstones	600— 750

	Feet below surface.
Light grey mudstones with carbon and dark shales with pyrites, light grey micaceous sandy shale	750— 830
Grey mudstones with bands of pyrites and quartzites ..	830— 950
Light grey mudstones, dark grey shales with pyrites and carbonaceous patches	950—1035
Yellow grits, carbonaceous slates, black grits, and dark grey micaceous shales	1035—1320
Dark carbonaceous shales with pyrites, bands of dark dolomite limestones	1320—1360
Dark micaceous shales, no record owing to the nature of the bore material	1360—1418

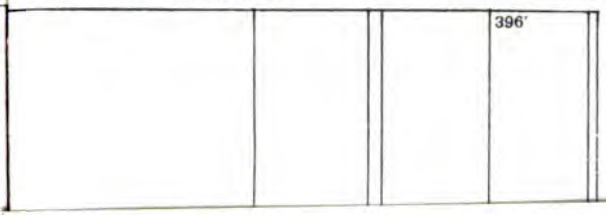
In February, 1905, Mr. A. Gibb Maitland examined a portion of the Greenough River in this vicinity and made the following field notes:—

Near Bindoo, on the Greenough River, are many large boulders of granite and other crystalline rocks; these suggest the occurrence of a boulder conglomerate although none were seen *in situ*. From Bindoo the track traverses a heavy sandplain as far as Noondamarra Pool (265). The bed and banks of the river are occupied by a bed of massive grit, with a decided dip up-stream. Some of these sandstones are seamed with thin veins of quartz, one conspicuous network of these lies about a mile south of Noondamarra Pool; it has a general dip of N. 25 W., and a high underlie to the east. About half-a-mile west of this is another more conspicuous quartzose zone, which stands out in bold relief and rises to a considerable height above the surrounding country. The linear persistence of these bands is very suggestive of their being due to the deposition of silica along lines of weakness (*i.e.*, faults, joints, or crushes). In the vicinity of Coonawa Crossing above the junction of Wooderarring Creek and the river the ground is strewn with quartz and other pebbles suggestive of their being derived from a conglomerate, a few boulders of which are to be seen in one or two places. At the crossing is a quasi-vitreous quartzite. Barraweelbarra Hill, a low tableland on the eastern side of the Greenough River, is made up of a bed of sandstone; on the northern slopes of the hill the ground is strewn with pebbles and boulders of the older crystalline rocks, which suggests their being the debris of the basal conglomerate of the series. In the vicinity of Kolanadgee Well the older crystalline rocks first make their appearance *in situ*, the junction therefore of the coal measures (?) is between this point and Barraweelbarra Hill. At a point about a mile or so down Wooderarring Creek, below No. 1 well on the Stock route, the sedimentary rocks give place to schists which are inclined at a high angle to the north-west. At the well the schists are succeeded by granite which occupies the country as far as the township of Mullewa.

In 1906 the New Depot Hill Coal Prospecting Association contemplated resuming boring operations but on the recommendation of the Government they transferred their attention from the Irwin to the country around Eradu, and a subsidised bore was put down about ¾ mile northerly from the Railway Station in the river bed to a total depth of 297ft.; a seam of brown coal was met with at 118-124ft. but the coal was of a hydrous nature; a sample [7120]

BULLETIN N°38 PLATE VI.

CALYX BORE



depth had been reached. In this bore the sandy

coal was of a hydrous nature; a sample

Moisture	9.59
Volatile carbon	40.28
Fixed carbon	37.97
Ash	12.16
	100.00
Colour of ash	white
Coke	none
Calorific value, B.T.U.	9900

Mr. Simpson reported that:—

. . . . it is a very dull, friable coal, which appears to be much weathered and may therefore improve at a greater depth in the basin. Its calorific value is equal to that of the lower grades of Collie coal.

Several hand bores were put down adjacent in order to determine the direction and amount of the dip of the coal seam, and from the data obtained from bores Nos. 3 and 4 the dip was calculated to be 5deg. 33min. and its direction 94 deg.

The following are the positions of these hand bores, which are all in the river bed:—

No. 1 is 272ft. bearing 262½, from the S.W. corner peg of Loc. 2208 [**7297**].

No. 2 is 110ft. northerly from the west abutment and 65ft. from the first pier of the railway bridge [**7380**].

No. 3 is 282½ft. bearing 355deg. from the calyx bore [**7381**].

No. 4 is 295min. 7sec. bearing 292deg. from the calyx bore [**7382**].

In hand bore No. 1 a large seam of inferior brown coal was met with at 87 to 115ft. depth, with a 2ft. parting of grey shale. The site is about 30 chains down stream, for which an allowance of 4ft. is necessary to be made, in comparing its level with the seam in the calyx bore, making its centre 105ft. as compared with 121ft. in the latter. Particulars of the strata met with in these bores are given in Plate VI.

The site chosen for the Company's deep bore is about 70 chains easterly on the north side of the railway line, about 10 chains east of the 35 mile post where there is a level piece of the railway, and the bore site is about 6ft. below this, viz., 523ft. above the sea-level. The river bed at the railway bridge is 444ft. and allowing 10ft. rise to the calyx bore site, there would be a difference of 69ft. between the two bores and the depth at which the coal might be expected at the calculated dip would be 700ft. Operations were begun in 1908, but up to the time of writing this report (August, 1909) only 615ft. depth had been reached. In this bore the sandy beds disap-

peared at 193ft., below which only blue clay with shaley bands has been met with [8812].

It appears probable that the sand, sandstones, shales, and brown coal in these bores belong to the Jurassic age, but there are no fossils to assist in this determination. These blue clays and shales met with in the bore come to the surface in Northern Gully about 9 miles north-west from Eradu and extend northwards 20 miles to the Yuna district, and have been tentatively mapped as Jurassic, though very similar beds occur in the Greenbrook and Irwin River valley and are there considered to be of Carboniferous age.

In 1906 Mr. A. Gibb Maitland, reporting upon the results of the geological survey by myself of the Greenough River as far as Eradu, states:—

An inspection of the sketch map showing the northern extension of the Irwin Coalfield, which is attached, indicates that the Carboniferous rocks occur not only in the valleys of the Irwin but in the Greenough River about due north of its junction with the Kockatea Creek. The Mullewa bore failed to reach those beds, hence the object it was sunk for has not been accomplished. If the prevailing dip of the strata be to the east, then a series of shallow holes to the west of the 1,418ft. bore should definitely settle the question as to the occurrence of coal seams in the Greenough River valley. I am therefore of opinion that the four or five shallow bores (not exceeding 300ft. each in depth) sunk at equal intervals in the Greenough River valley between the crossing of the railway line and the junction of the Greenough and Kockatea Creek would afford decisive information, and settle for all time the question of the occurrence of commercial coal in this vicinity. I am not, however, very sanguine that such will be found.

On 17th February, 1909, Mr. A. Gibb Maitland reported further in favour of those bores being undertaken, and they were commenced shortly afterwards, and thirteen bores have now been completed.

The following are the sections of the strata pierced in the bores completed up to date:—

No. 1 Bore, Kockatea Creek [8866].

	Feet below surface.
Sand	18
Blue clay	48
Blue clay with pyrites nodules	57
Stiff blue clay	100
Grey sand with fragments of granite	127
Grey sand with pyrites nodules	133
Mottled white and grey clay	144
Coarse quartz sand and shale fragments ..	148
Hard grey clay and shale fragments	155
Grey shale with fragments of slate and granite	175

No. 3 Bore, Kockatea Creek [8881].

	Feet below surfac
Sandy loam	10
Yellowish white clay (? shale)	20
Grey clay shale	41
Grey clay shale with pyrites	58
Debris of somewhat sandy shale	63
Chocolate coloured clayey shale	86
Debris of sandy shale with granite pebbles	109
Sand with granite pebbles (fine conglomerate)	110
Chocolate coloured shale	140
Clay (? shale) with granite pebbles	152
Debris of sandstone or grit	178
Debris of sandstone and grit	191
Debris of conglomerate	201

No. 5 Bore, Kockatea Creek [8964].

Surface debris	4
Sandstone mixed with limestone	12
Yellow shale	18
Grey shale with granite boulders	135
Black shale	200
Grey shale	?

No. 7 Bore, Kockatea Creek [8989].

Yellowish brown sandstone	8
Yellowish clay shale	26
Sandstone	29
Sandy shale	200

No. 9 Bore, Kockatea Creek [10578].

Clayey sand with waterworn boulders	10
Chocolate-coloured clay shale	30
Grey sandy shale	56
Clayey sandstone with pyrites	113
Fine grained sandstone	148
Debris of sandy shale	151

No. 11 Bore, Kockatea Creek [10579].

Laterite	8
Fine grained yellow sandstone	18
Grit	46
Sandstone	81
Sandstone	113
Debris of clayey sandstone	115
Sandstone	130
Debris containing quartz, mica, pyrites nodules, and granite. (?) Conglomerate or bedrock	141

	Feet below surface.
No. 13 Bore, Kockatea Creek [10580].	
Gravel	7
Sandstone	30
Shale	114
Granite	115 6in.
Note.—This is the first hole to strike bottom.	
No. 15 Bore, Kockatea Creek [10581].	
Hard yellow sandstone	50
Light grey gritty shale	53
"Granite" (no sample sent)	54
Debris, disintegrated granite	?
No. 17 Bore, Kockatea Creek [10582].	
Loam (sample missing)	9
Hard ferruginous sandstone pebbles	11
Fine soft yellowish sandstone	33
Grey micaceous clay shale	36
Gritty micaceous clay with granite boulders	40
Debris from granite, etc (stream bed deposit)	41
Granite	?
No. 19 Bore, Kockatea Creek [10788].	
Brown sandy soil	8
Soft grey very porous sandstone, gritty in parts	20
Slightly ferruginous grit	23
Stiff white clay gradually passing into a	34
Stiff grey clay	46
Soft gritty sandstone	60
Stiff dark grey clay	71
Light grey sandy clay	77
Stiff mottled reddish clay	84
Brownish grey clay	112
Very dark, almost black, clay	115
Very dark, almost black, sandy clay	117
Light grey clay	124
Soft fine whitish sandstone	129
Yellowish clay	136
Mottled pinkish clay	139
Greenish grey clay	190
Coarse grey crumbly sandstone	196
Whitish clay with sandy bands	200
No. 21 Bore, Kockatea Creek [10915].	
Reddish sandstone (superficial deposit)	20
White clay (? shale)	46
Grey clay shale with pyrites nodule	66
Debris of fine conglomerate	67
Sandstone	98
White argillaceous sandstone	168
Do. do.	192
Sandstone	200

	Below surface.
Brown crumbly sandstone (superficial)	16
Brown gritty sandstone (superficial)	19
White very fine sandstone	54
Dark grey clay	103
Grey clay shale with pyrites	104
Dark grey—almost black—clay	126
Grey gritty clay shale with pyrites	127
Light grey sandy clay	200

No. 25 Bore, Kockatea Creek [10917].

Brown crumbly sandstone (superficial)	20
White clay	26
White soft and fine sandstone	95
Grey clay shale	120
Almost black clay shale, suggests coal	124
Light grey clay	160
Black clay shale, poor coal	168
Light grey clay	200

It may be somewhat premature to give an opinion upon these results, but the impression left on the mind by an inspection of these samples is that they are of Carboniferous age and the map has been coloured accordingly.

Ice-scratched Boulders, Irwin River.

Fig. 14.

Coal indications have been reported at various times to exist in the Lynton District and a shaft was sunk in Loc. 2395 by one of

the Gregory Brothers, but no record of the depth or of the strata has been kept and no water or coal was found. The dump shows only sand, sandstone, and thin flaggy ironstone, all evidently of Jurassic age.

Ice-scratched Granite Boulders embedded in Blue Clay, Irwin River.

Fig. 15.

Another place thought to have more favourable indications is the junction of the Hutt River and the White Water, 2½ miles

this locality but no fossils or clay or shales were found that might give any hope of carbonaceous beds existing there.

Glacial Erratic Boulders.—At about the middle of the series of Carboniferous clays there is a zone in which many erratic boulders of crystalline rock occur, comprising granite, gneiss, amygdaloids, quartzites, also sandstones and chalcedonised sandstones and limestones, mostly rounded and many with smoothed surfaces and some with well-defined grooves and cross-scratchings, such as only glacial action can produce. These form in places extensive boulder beds or outcrops which occur at distances of from 5 to 10 miles from the main granite margin. These erratic blocks are mostly identifiable with rocks forming the tableland eastward of the main granite range. The largest outcrop of the boulder beds is on the west side of the Irwin River at Nangatty, and is about four miles long and two miles wide; see Figs. 14 and 15. Another patch lies about two miles to the south-east, see Fig. 16. There is here a large erratic quartzite boulder called the "White Horse," and although partly imbedded in the ground it is

Ridge of Glaciated Boulders, two miles S.E. of Loc. 1168, Irwin River.

Fig. 16.

7ft. high by 18ft. by 13ft., see Fig. 17 [7788]. Between these two places there is a smoothed granite boulder imbedded in the blue Carboniferous clay forming the banks of the Irwin River, see Fig. 18. The height of the top of the hill with the boulders is 1,102ft., whilst the river bed is 672ft., showing that the range of these boulders is at least 430ft. in the strata.

At the coal seams also at the south branch of this river there were some very decomposed granite boulders to be seen in the clays and shales, the elevation here is 890ft. Eight miles southerly a well

Erratic Boulder, 1½ miles S. of Loc. 1168, Irwin River.

Fig. 17.

scratched quartzite pebble was found by the writer on the top of the highest of the Brockman Hills (granite), the elevation being 862ft.

Glaciated Granite Boulder embedded in Blue Clay with Calcareous Bands, Irwin River.

Fig. 18.

About two miles south-easterly from there, in Loc. M69, near the south-east corner of M335, on the low rise (683ft. elevation), some very fine samples were found. Another exposure occurs eastward

of Beatonfield, at an elevation of 800ft., and there are here many large granite, quartzite, and chalcedonised argillaceous limestone boulders; the latter have become weathered into picturesque markings and shapes similar in character to the festoon-like silicifications of the Coorow Cave, see Fig. 10. At a spot marked on the map as "Erratic Blocks," about seven miles south from here, a little to the west of Mount Scratch, there is another outcrop on a spur of the hill at an elevation of 100ft. This may be of Recent date, as the blocks are in a high level gravel.

Some blocks of chalcedonised rock, 6ft. long, were also noticed in the gravel resting on the top of the white sandstone escarpment on the east side of Loc. M. 331. All these blocks appear to be of local origin, and the boulder beds probably represent terminal moraines of the glaciers that at that period evidently descended from the plateau into the sea, and the blue clays represent the subaqueous deposit of glacial mud or till. Twenty-four samples of the erratic blocks were collected [**7657, 7788/9, 7790, 7805/6, 7844, 7847/9, 7850, 7883/9, 7890/2, 7903/4, 7906**]and four sets of glaciated boulders [**7706, 7853, 7873/4**]. These glaciated blocks are taken to be of Carboniferous age, and distinct from the deposits at Mt. Hill in the "Recent" section.

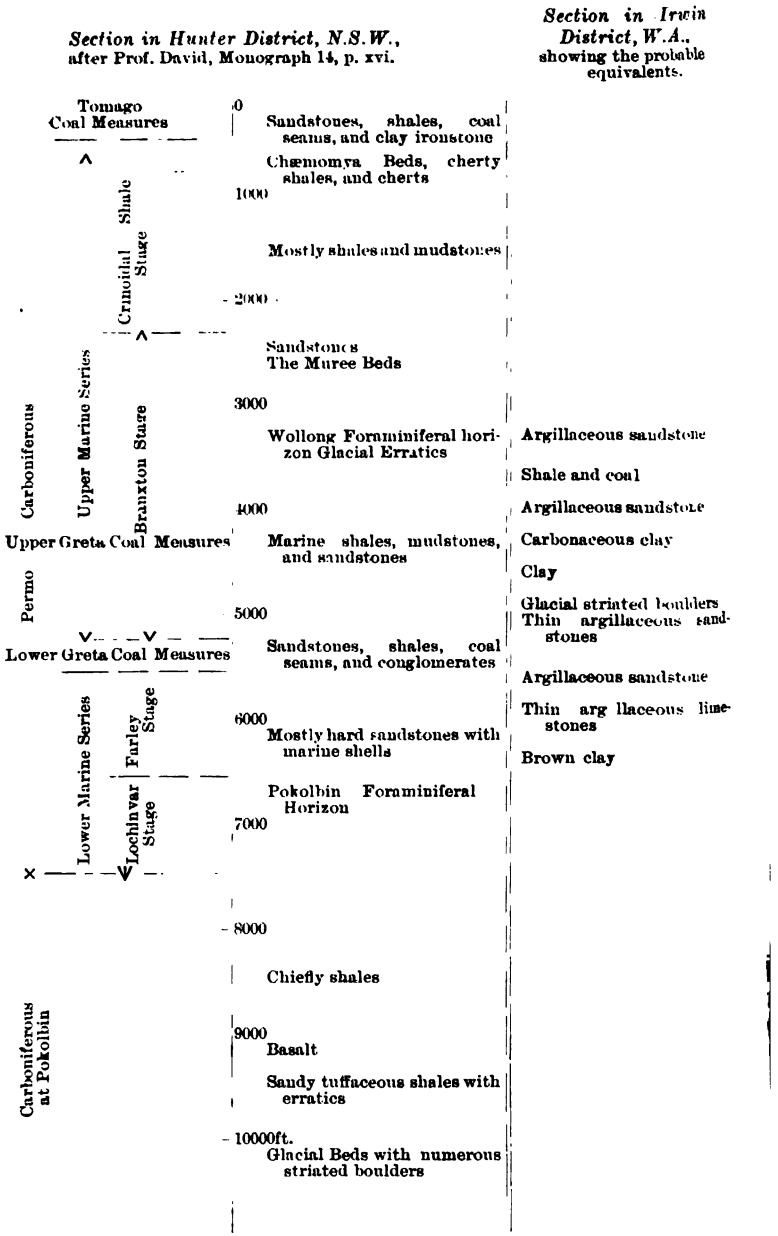
About 48 miles in a direct line north-westerly from Mingenew at the Granite Ridge, near the east end of the Georgina road, Greenough district, there is a small remnant of a boulder deposit forming a small flat-topped hill which has traces of a laterite capping, its elevation being 734ft. It has probably the same glacial origin as that of the Irwin district and it may be of the same age. The boulders are mostly composed of a fine porphyritic grey granite with a few quartzite blocks which are embedded in an indurated clay and are much decomposed, and their margins frequently show ferruginous discolouration caused by zone decomposition, and when broken show a slickenside fracture, as does also the clay matrix. The thickness exposed is about 20 feet. [**8067/9, 8070/3.**]

The glacial boulder bed marks an important horizon in the strata as it can be correlated with other localities, for the same bed appears to have been found by Mr. A. Gibb Maitland, in the Gascoyne district, 300 miles northward from here (see Report of the Geological Survey for 1900, p. 29 and plates, also Bulletin No. 10), and it may be equivalent to the glacial boulder bed of the Branxton series of New South Wales that overlie the Greta or Lower Coal Measures which separate the Lower from the Upper Marine series of the Permo-Carboniferous Age; evidences also have been found at Bacchus Marsh in Victoria, Wynward in Tasmania, Hallett's Cove in South Australia, and also in other countries as in the Talchir Beds of India and in South Africa. See Prof. David's account forming No. 4 of the New South Wales Geological Memoirs, p. 337, and the General Section No. 2, and Messrs. Chapman and Howchin's account of the Foraminifera of these beds, Palæonto-

logical Memoir No. 14, New South Wales, from page xvi. of which the following table has been adopted:—

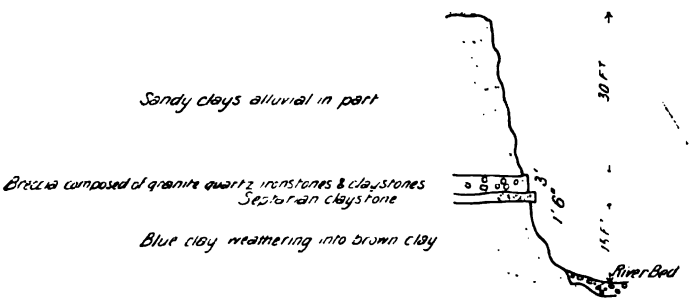
Fig. 19.

COMPARATIVE SECTIONS.



In South Africa the equivalents to these Carboniferous and Permo-Carboniferous glacial beds occur at the base of the Karroo system of that country and appear to be of vast extent; they have been divided into a southern and northern series, the former being sub-aqueous and the northern true ground moraines, occurring at an altitude of about 4,900 feet above sea level with glaciated rock surfaces having striæ over 300 miles in length, the direction being from north to south, see "A Contribution to the Study of the Glacial (Dwyka) Conglomerate in the Transvaal," by E. T. Mellor, Quarterly Journal of the Geological Society, Vol. LXI., p. 679. One of the illustrations of that paper has a remarkable similarity to the views here produced.

CONCRETIONS.—The clays of Carboniferous age exposed in the beds of the Irwin River above Yaragadee and its northerly branch to Nangatty have numerous septarian concretions in well-defined horizons. At the horseshoe bend of the river near Yaragadee there is a massive layer eighteen inches thick as shown in the sketch (Fig. 20), and fur-


Sandy clays alluvial in part
Breccia composed of granite quartz ironstones & claystones
Septarian claystone
Blue clay weathering into brown clay
30 ft
River Bed

SKETCH OF RIVER CLIFF NEAR YARRAGADEE

Fig. 20.

ther up the river and in its northern branch there are zones with oval rolls and discs or spheroids; the former can be seen near the track crossing the branch near the northern boundary of Block 1899. They are sometimes six feet long, fifteen inches wide, and six inches thick, formed in ripple-like order a few yards apart, having a north-westerly direction. Similar rolls can be seen north west of Loc. 1168, Irwin River, where they have a direction of 262 degrees. The discs or spheroids attain eighteen inches diameter and always occur flatways with the bedding of the strata. Occasionally some small and thin ferruginous discs up to two inches in diameter occur but in all other instances the concretions are calcareous with calcite veins

usually permeating them, see Fig. 21. Diligent search was made for any indications of organic kernels but without success; were such

Calcareous Concretion, Irwin River.
Fig. 21.

organic centres present the explanation of the origin of the concretion would be that it had been induced in some way by the action of salts of lime and iron upon organic particles. The massive layers may be partly due to original sedimentation but other causes have assisted in the precipitation of calcium carbonate and it has been found that peaty matter produces this from solutions of calcium chloride and sodium carbonate. Bacteria also have been found to bring about the deposition of calcium carbonate from solutions of calcium sulphate representing the calcium sulphate of sea water when ferric oxide is in the deposit or mud, the bacterial jelly behaving in a similar way to the peaty matter. This subject has been dealt with by Mr. H. B. Stocks in a paper read before the Geological Society of London in February, 1902, see page 46 of No. 229. Vol. LVIII., Quarterly Journal of the Geological Society. He summarises as follows:—

Coal was formed by stagnant sea water by anærobic decay brought about by bacteria; the calcium sulphate in the sea water reduced and

of water-logged vegetable matter and then around it, forming a concretion which grew in the bacterial jelly and hence acquired its rounded shape. At the same time sulphide of iron was formed from the iron in the fine mud and became part of the concretion thus formed, being subsequently converted into iron pyrites by pressure or some other agency.

The calcareous concretions have an economic value for cement manufacture. The following is the result of an analysis made in the Laboratory of a mineral specimen [**7672**] :—

Silica	13.58	Equal to calcium carbonate 73.29.
Alumina with a little iron oxide ..	8.12	
Lime	41.08	

The analyst remarks that it should be well suited for making Portland Cement without the admixture of any other material.

Coal.—The journals of Messrs. A. C. and F. T. Gregory, 1846 to 1858, were published by the Queensland Government in 1884, and on p. 8 is the account of the expedition to the east and north of Swan River which left Mr. T. N. Yule's station, in the Toodyay District, 60 miles north of Perth, on the 7th August, 1846. Under date 9th September—

At 1 p.m. entered a deep valley by an abrupt descent and found ourselves once more on the banks of the brackish stream, which was much enlarged, and running through a narrow grassy flat backed by high sandstone cliffs from 80 to 100 feet high. Continuing our course along the river west till 1.55 p.m., when it turned north, and at 2 p.m. north-west; at 3 p.m. the banks of the stream became very high and stratified in a remarkable manner, the lower rocks in thin beds dipping to the east, whilst the superincumbent rocks of red sandstone were horizontal. We therefore entered the bed of the river to examine it and found two seams of coal, one five feet thick and the other about six feet thick, between beds of sandstone and shale. Having pitched the tent and tethered the horses, we commenced to collect specimens of the various strata and succeeded in cutting out five or six hundredweight of the coal with the tomahawk, and in a short time had the satisfaction of seeing the first fire of Western Australian coal burning cheerfully in front of the camp, this being the first discovery of coal in the western part of the continent.

The Government followed up the discovery by despatching Lieutenant Helpman in the colonial schooner "Champion" to procure a bulk sample, with a volunteer party:—

to Champion Bay, now the site of Geraldton, and thence by land to the coal-seam on the Irwin River, a distance of 90 miles, and brought down about three cwts. (see original journal) of coal to the vessel. Mr. Gregory states on p. 11 that "this coal, though of fair quality and suitable for steam purposes, proved, however, to be so remote from any suitable port for shipment that it has hitherto not been available for commercial purposes."

The occasion was the subject of a confirmatory notice of the discovery in the Western Australian "Government Gazette" of 8th January, 1847. In the latter part of the same year, Dr. von Sommer made a geological examination of the Victoria district and visited

this coal outcrop but he did not think much of the coal, for in his report dated 20th October he says:—

The coal even of the second seam (the first being about 5ft. thick) did not contain bitumen in any perceptible degree and produced a large quantity of clayey ashes.

About this time the Legislative Council declared a reserve of 10,000 acres to include these coal seams. This became Reserve No. 900, two miles square (2,560 acres), which was surveyed here in the year 1871 by Mr. John Forrest to include the coal seam; it was not numbered till the year 1885 and was not gazetted till 25th May, 1893, but was set apart as a reserve for coal. In the year 1893 the Government relinquished nearly one-half of this large reserve, diminishing it to 1,420 acres to meet the objections of the Midland Railway Company, for by Clause 50 of the contract of 1886, with the Company, the power of making reserves was confined to necessary reservations for roads and other public purposes. The portion relinquished comprised all that lay on the eastern bank of the river and moreover contains the dip of the seams.

The Rev. C. J. Nicolay examined the locality of the coal seams, which are on the south branch of the Irwin River about one mile above the forks, and his visit is probably connected with the grant of €100 that was made by the Legislative Council in the year 1879, with the aid of which a shaft 50ft. deep was sunk. This is probably the well-slabbed shaft 5ft. by 7ft. which is on the east bank above flood level about a mile farther up-stream from where the outcrops occur; it did not reach coal and judging from the material in the dump the shaft is wholly in blue clay.

There are two pairs of outcrops of coal seams in the river bed at the first mentioned locality, a few chains distant from each other. At the northern one there are two seams about a foot thick of a soft hydrated coal associated with shales and clays, at the other one there are two thicker seams of carbonaceous material softer and more shaley than the others and in more sandy strata. The underlay is 10 deg. to the east. The salinity of the shales is a remarkable feature, for some of the beds at the time of this survey were white from efflorescence of the salt contained in them. About half a dozen small prospecting shafts have been put down in the river bed here principally at leases 102 and 103, and are now always full of water, but both this and the northern branches of the river are dry during the greater part of the year. There are, unfortunately, no records to show the character of the strata passed through in these shafts.

In the year 1888 Mr. James Bell, while out cattle-hunting, found a lump of coal in the bed of the north branch of the Irwin River which he took to Geraldton, and Mr. Elliott came out with him and after searching the country they discovered the seams in the face of the hill near the river. This is about 19 chains north from his selection 943, where there is now a cattle yard; subsequently all the

land about these coal seams was surveyed for mineral leases. The Irwin Coal Mining Company was formed in Geraldton by Messrs. Bell and Elliott soon after their discovery, to work this coal under lease from the Government, and it united with others and became the Amalgamated W.A. Coal Company, and they put in a drive about 200 feet in length on the underlay of the strata, 10 deg. to the east, also two other trial drives and a small shaft at the two other smaller seams at a lower horizon than the main seam. A large vertical shaft was also begun about ¼ mile away towards the Bigarra Spring, a bore was also put down about 70 feet but the locality is not now definable and neither reached any coal. Altogether about 20 to 50 tons were taken out of the main drive and carted to Walkaway and Geraldton, and it is stated to have been tried with good results in the *Rob Roy* vessel which steamed from Geraldton to Fremantle, but made a good deal of clinker, partly owing, it was thought, to its being surface coal. I was informed by Mr. Bell that an engine was driven up to Chidlow's Well from Perth, using coal from here by an engine-driver of the name of Williams.

On 5th September, 1891, the Midland Railway Company selected Block 1908, and on surveying it and a number of mineral leases it was found to include these coal leases; work was therefore discontinued on the latter and a refund of £150 was made to the holders by the Government. The Company refused to continue the

Drive on Coal Seam in Reserve 2297. Irwin River (in flood).
Fig. 22.

leases as they said that they intended to work the seams themselves, but owing to financial difficulties were unable to do so. No mining leases have since been granted by the Government on the reserves

on which the original leases were partly situated. Reserve No. 2297 of about 200 acres was made in 1893 as a resting place for travellers and stock (public utility), and it included the Doghole or Bigarra Spring and Bell's coal seams. It was gazetted on 25th May, 1893.

In July, 1907, the Midland Railway Company, before their land sales in the neighbourhood, unwatered the drive and hewed from its sides about six tons of coal which were taken to Midland Junction, but no results have been announced.

The outcrop of the seam at the drive is 3ft. thick but farther in the seam widens to 5 feet, showing 1ft. 9in. of fairly good quality coal in the middle [**7494**] and a lower quality, 1ft. 3in., thick, above and 2ft. below [**7463, 7465**]. The roof is composed of shale and sandstone and the floor is indurated clay. It seems unfortunate that operations were given up as the seam is a promising one. A preliminary visit was made here on the 29th July, 1907, when the river was in flood (Fig. 22), and the second visit was made on 31st October, when the pools in the river were rapidly drying up. The water above Loc. 943, though slightly saline, is drinkable, but at that spot a very saline spring which is permanent in the river bed spoils the water for miles down stream. (Water sample No. 8.)

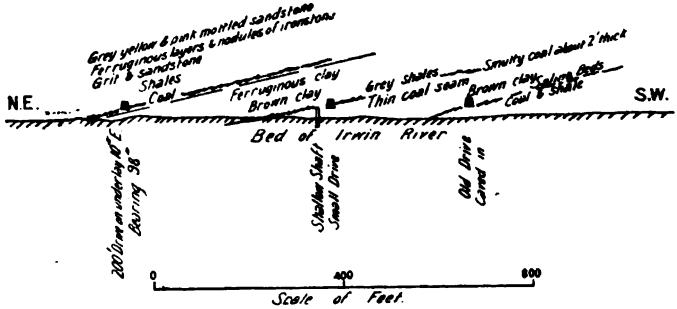


Fig. 23.

The Laboratory report is as follows:—

The samples of coal from the Irwin River Reserve 2297 are of the hydrous bituminous non-caking class. The coal is somewhat fragile, and made up of alternate layers of bright and dull coal with partings of soft "Mother of Coal." The following figures were obtained in testing it:—

	Top of seam. [3569]	Middle of seam. [3570]	Bottom of seam. [3571]
Moisture	22.04	24.74	24.25
Volatile hydrocarbons..	23.84	27.12	26.73
Fixed carbon	37.25	31.98	37.97
Ash	16.87	16.16	11.05
	100.00	100.00	100.00

Calorific value, lbs. ..	7.26	..	7.43	.. 8.24
Evaporative power, British thermal units ..	7020	..	7182	.. 7965

The ash and moisture are both very high, and the calorific value correspondingly low. The coal, however, will doubtless improve at a greater depth.

The only other locality where carbonaceous seams were noticed outcropping was at the Woolaga Creek, about 2¼ miles south of Ebano Spring; they are about 3 inches thick, associated with blue clays and shales underlying 11 degrees north-easterly; no prospecting work appears to have been done here.

Fossils.—There do not appear to be any fossils in the strata immediately adjacent to the coal seams, nor anywhere on the eastern side of the river, but Carboniferous fossils occur on the western side of the Irwin River in the cliff which extends from five to fifteen chains below Loc. 943, so that the coal seams are presumably only of Carboniferous age. In the western cliff there are four zones of claystones, each ranging up to two feet in thickness. The total height of the cliff is about forty-six feet, the intermediate spaces being composed chiefly of current bedded sandy clays and shales, friable enough to be worn away gradually by subaerial action, leaving the

Irwin Valley, Fossil Cliff on the right.

Fig. 24.

delicate *Spirifera* shells and the more solid *Crinoid* weather out and fall to the foot of the cliff in a beaut state of preservation; minute *Foraminifera* also occ

in these beds. In the harder bands are the larger shells of *Productus*, *Aviculopecten*, *Bellerophon*, and *Orthoceras*. Several portions of articulated crinoid stems were noticed in the lowest band, but were too solidly embedded to be readily extracted; in all other instances the crinoid segments were separated. Fig. 24 [7795 7].

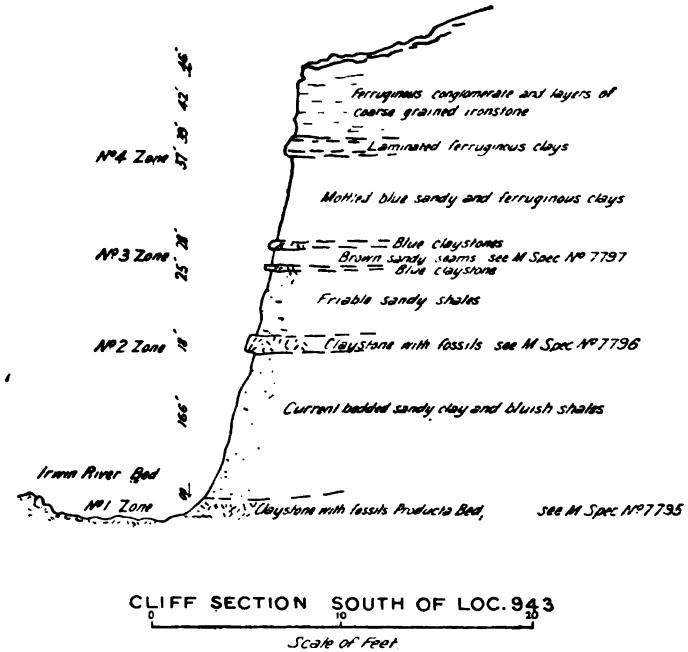


Fig. 25.

About ten chains down the river below the fossiliferous cliff represented in the above figure there is a remarkable cliff on the opposite bank, 300 feet in height. It does not appear however to

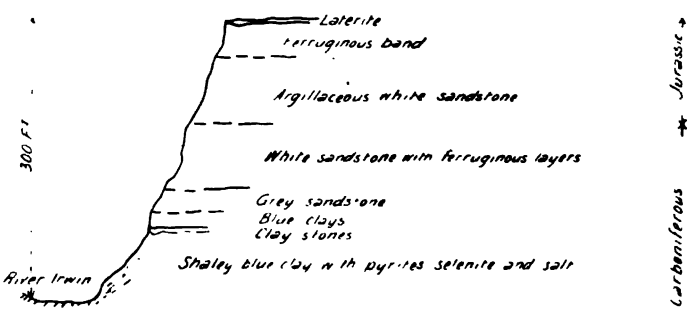


Fig. 26.

have any fossils. This cliff is represented in th
gram, and in Fig. 26.

The following list of fossils are characteristi
(see Annual Progress Report of the Geological S
p. 20):—

Dielasma nobilis, sp. nov.
Spirifera, sp. ind.
Cyrtina carbonaria, var. *Australasica*, Eth. f
Cleiothyris Macleayana, Eth. fil.
Productus subquadratus (Morris), Eth. fil.
Chonetes, sp. ind.
Aviculopecten subquinquelineatus, McCoy.
Modiola (?), sp. ind.
Myalina (?) *Mingenewensis*, sp. nov.

Mr. Etheridge states that "only four species ar
identical with forms found in the Permo-Carbonif
in Eastern Australia, viz.: a Foraminifera (*Nu
ductus subquadratus*, *Fenestella fossula*, and *Aviculo
[**5706**b, **5708**, **5702**].

The following fossils have been collected here b
Jackson, then Assistant Government Geologist, and
tified and described by Mr. R. Etheridge in Bullet
26 to 33:—

Foraminifera—*Nubecularia lucifuga*, var. *Step
[**5706**b, **5710**].

Actinozoa—*Pleurophyllum Australe*, Hinde [**57**

Brachiopoda—

Productus semireticulatus, Martin [**5708**a, 5
Productus subquadratus, Morris [**5708**d to
Productus tenuistriatus, var. *Foordi*, Eth fi
Productus undatus, Defrance [**5705**, **5706**c],
Seminula subtilita, Hall [**5706**a, **5707**].
Reticularia lineata, Martin [**5706**-**5708**e].
Chonetes Pratti [**5705**, **5708**l], [**5710**].
Dielasma [**5708**m].

Polyzoa—*Fenestella fossula*, Lonsdale [**5702**, **57**

Lamellibranchiata—

Aviculopecten Sprenti, Johnston [**5706**c, **57**
Concordium (internal cast) [**5702**].
Stutchburia cf. *Stutchburia* (*Pleurophorous*)
fil. [**5702**, **5711**, **5711**a].

The following list of fossils collected at the Fossil cliff, north branch Irwin River, during this survey has been prepared by my colleague Mr. L. Glauert:—

	Invertebrata.	Lower Zone.	Middle Zone.	Upper Zone.
Foraminifera ..	1. *Nubecularia Stephensi*, Howch. ..	..	*	*
Actinozoa	1. a ? *Zaphrentis*, sp.	..	*	..
	2. *Pleurophyllum Australe*, Hinde ..	*	*	*
	3. a ? *Coral* differing from the above in the number of septa and in the presence of dissepiments	..	..	*
Crinoidea	1. *Actinocrinus*, segments of stalk ..	*	*	*
	2. *Platycrinus*, segments of stalk ..	..	*	*
Brachiopoda ..	1. *Productus semireticulatus*, Martin	..	*	*
	2. *Productus subquadratus*, Morris ..	..	*	*
	3. *Productus tenuistriatus*, var. Foordi, Eth. fil.	*	*	*
	4. *Productus undatus*, Defrance ..	..	*	*
	5. ? *Productus*, sp. Brachial valve ..	..	*	..
	6. ? *Aulosteges Baracoodensis*, Eth. fil.	..	*	..
	7. a ? *Streptorhynchus*, sp.	*	..	..
	8. a ? *Strophomena*, sp.	..	*	*
	9. *Cleiothyris Macleayana*, Eth. fil...	..	*	*
	10. *Seminula subtilita*, Hall	*	*	*
	11. *Terebratula hastata*, Sow.	*	*	*
	12. a ? *Spirifera duodecimcostata* ? ..	*	..	*
	13. ? *Spirifera Hardmani*, Foord ..	..	*	*
	14. *Spirifera Musakheylensis*, Dav. var. *Australis*, Foord	..	*	*
	15. *Spirifera lata*, McCoy	..	..	*
	16. a ? *Spirifera striata* ?	..	*	*
	17. *Syringothyris exsuperans*, portion of valve	..	*	..
	18. *Reticularia lineata*, Martin ..	..	*	*
	19. a ? *Reticularia* ? (Orthis ?) ..	..	..	*
	20. *Chonetes Pratti*, Davidson ..	*	*	*
	21. *Reticularia crebristria* ? Martin ..	..	..	*
Polyzoa	1. *Fenestella fossula*, Lonsd. ..	*	*	*
	2. a ?	..	..	*
	3. a ?	..	..	*
	4. a ?	..	..	*
	5. a ?	..	..	*
Lamellibranchiata..	1. *Deltopecten subquinquelineatus*, McCoy.	..	..	*
	2. *Aviculopecten tenuicollis*, McCoy ..	..	*	*
	3. a ? *Modiola*, sp.	..	*	..
	4. a ? *Modiola*, sp.	..	..	*
	5. a ? *Stutchburia*, sp.	..	..	*

List of Fossils Collected—

Invertebrata.

	6. a ? *Edmondia concentri*
	7. a ? *Sanguinalites Ethe*
	8. a ? *Sanguinolites*, sp.
	9. a ? *Sanguinolites*, sp.
	10. a ? *Schizodus*, sp.
	11. a ? *Pinna*, sp. ..
	12. a ? *Arca* (*Palæarca*), s
	13. ? *Pachydomus*, sp.
	14. a ? .. .. ..
Gasteropoda and Heteropoda	1. *Bellerophon costatus*, S
	2. a ? *Bellerophon*, sp.
	3. a ? *Acroculia*? *Platycer* Phill.
	4. a ? *Euomphalus Diony*
	5. a ? *Euomphalus*, sp.
	6. a ? *Euomphalus* (*Turb*
	7. a ? *Pleurotomaria sequ*
	8. a ? *Pleurotomaria natico*
	9. a ? *Pleurotomaria*, sp.
	10. a ? *Pleurotomaria*, sp.
	11. a ? *Pleurotomaria*, sp.
	12. a ? *Pleurotomaria*, sp.
Cephalopoda ..	1. a ? *Orthoceras*, c.f. *long*
	Vertebrata.
	1. a ? This specimen may though it resembles *ceras* figured in the Pa of New South Wales
	2. a ? Bones .. ..

Note.—Specimens marked "?" are doub "a" have not been recorded for Western Aus gathered from the materials available.

Numerous fossils from this locality hav A. H. Foord in the Geological Magazine, V 155, pl. vi., vii., and an account of the Fora by Mr. Walter Howchin, Rept. Austrn. Vol. V., p. 366, also Trans. Royal Society o XIX., 1895, pp. 194-200, pl. x. In Mr. Fo are of Carboniferous age, and Prof. David

If this view be accepted (and the strongly supports it) the Irwin River district ha as well as a glacial horizon, of Carboniferous the Permo-Carboniferous foraminiferal and South Wales.

Reference has also been made to this place by Prof. T. W. E. David in the New South Wales Memoir No. 14, 1905, "On the

Upper Irwin River Valley, from the High Cliff, South of Reserve 2297.

Fig. 27.

Foraminifera of the Permo-Carboniferous Limestones of New South Wales," pp. xiii., xiv, with a sketch cross section. He was inclined to place the strata as Carboniferous.

White Cliff and Sandplain, South of Mingenew.

Fig. 28.

Fossils have also been found in the clays about 1¼ miles south-west of Gnoolowa Hill, about five miles westerly (see Bulletin 27, p. 36).

Mounts Victoria and Albert, Lynton.
Fig. 29.

inspecting the deep bore then in progress, and a few more specimens were collected; this is the southernmost of several low hills of

Sandstone Cliffs, Greenough River.
Fig. 30.

ferruginous sandstone, and the fossiliferous zone outcrops round the hill about 5 to 20 feet below the top. An old track from Mingenew passes on the south side between the hills, and the fossiliferous strata can be seen on this track [**354, 1903, 8015**]. A ferruginous dyke, about 9 inches wide, passes through this hill in the direction of 313 degrees and dipping 80 degrees to the west, and there are also

several other small ferruginous dykes in the adjacent hills [7866/7]. A somewhat similar formation occurs at Enanty Hill, about two miles northerly, and a pyriteous fossil bivalve shell was obtained here in sinking for a well recently [7714]; its designation has not yet been determined.

JURASSIC STRATA.

Over the denuded surfaces of all the preceding rocks and strata there were deposited a series of sandstones of great thickness; some of them are still very loose in texture, with a minor proportion of clays; others are very hard, ranging into ironstones; also shales with occasional small patches of lignite; the uppermost beds are limestone bands often fossiliferous. Some of the ferruginous sandstones have been found to contain fossil palms, reed stems, and wood. The series are nearly horizontal, and are probably undulating slightly, also the frequent current bedding causes some uncertainty in determining the dip (Fig. 31). They are frequently saline, and

Cliff showing current bedding, Greenough River.

Fig. 31.

have been probably deposited along the then coast during a long period of gradual depression of the land surface. The thickness of the strata must be quite 3,000ft., for the base of the series was not reached in the Racecourse bore near Geraldton at 1,531ft. depth, this, less 95ft. elevation of the bore site above the sea, gives 1,436ft. below sea-level; they also form the hills of which Wizard Peak is one, about 8 miles easterly from the bore 1,180ft. height by aneroid

barometer, which is about the level of the country at the deep
15½ miles eastwards of Eradu, proving a thickness of 2,516ft.
General Section, Plate VI., Bulletin 26).

Commencing at the south end of the district mapped cont
ously these strata can be described as occupying the white sandp
country of the Arrowsmith River from about 5 miles distance f
the coast where they are overlaid by the coast limestone to the
lying granite ridge of Arrino and Yandanooka, their boundary
thence through Mingenew to the Upper Irwin at Yaragade, N
gatty, Gnoolowa Hill and Edong towards the main granite ra
(Fig. 28). A remnant strip extends up along there from southwa
forming the outer portion of the main high lying ground of
country inland. From the Upper Irwin localities just mentio
they extend across to the Greenough River flats near Walka
and the granite tract around the homesteads of Glengarry
Tibraddon; from there they extend beyond Eradu towards
Kockatea Creek. From Eradu northwards they skirt the east
side of the granite and quartz conglomerate divide east of
Chapman River. From near Geraldton they form the long eleva
tract of which the Moresby flat-topped range is the southern
Norman's Well the northern termination; isolated remnants f
the flat-topped and conical hills in the Chapman valley and
liers towards the coast (Figs. 32, 35-8). A granite tract interve

Mount Summer. View across the Chapman Valley.
Fig. 32.

around Northampton, beyond which they continue north and nor
west towards or beyond the Murchison River where their bounda
has not yet been mapped.

These strata can be well seen in the high and steep ramp
escarpment that bounds the main inland plateau along the east
side of the Greenbrook and northwards to the Upper Irwin a
Greenough Rivers. It is composed of horizontally ferruginous a
friable light-coloured sandstones with occasional clay bands and el
sandstones, which cause springs to occur occasionally at varial
elevations in the face of the escarpment, as at De Burgh Spring

at the foot as at Ebano Spring. The edge of the escarpment is steep because the surface of the sandstone has been indurated by secondary silica or iron into quartzites and laterites which break away whenever the softer sandstone below it becomes eroded by atmospheric agency. The valley below is composed of blue clays and brownish-yellow sandstones of presumably Carboniferous age. Where this escarpment is cut through by rivers and watercourses deep gorges are formed, in some cases having a ravine-like character as in the Upper Irwin in the neighbourhood of the coal seams. Westward of the railway line at Arrino they attain about the same level as the escarpments, about 1,150ft., and form the sandplains already described, with occasional springs at the clay beds; these springs are mostly diatomaceous.

The cliffs or bluffs on the sandplains near Mingenew exhibit white sandstone with lower beds of very ferruginous sandstone. The latter form the hill to the north-west of the town, where there is a quarry. The same beds outcrop about 3½ miles due north of Mingenew at the same level, 880ft., and here a fine series of plant remains consisting of palm leaves, reeds, and wood were found. These evidently once grew where they are now found, and they are very welcome indications of the geological age of the beds; they have been submitted to Mr. E. A. Newell Arber of Cambridge as the best authority on the subject, and his report will appear in Bulletin No. 36 [**7722, 8104**]. His conclusions in regard to these specimens are as follows:—

Of the specimens examined, the fronds of *Otozamites Feistmanteli* Zigno, and the specimen compared with *Pagiophyllum* alone afford any evidence as to the age of the beds. These plants occur in the Jurassic of Europe, and possibly also in (?) Jurassic beds in Queensland. So far as a comparison with the European fossils is concerned the age would appear to be earlier rather than later Jurassic. *Feistmanteli* Zigno occurs in the Lower Jurassic of England and Italy, with which 8104 x, y, may be compared, a Lower Jurassic fossil from Germany. As regards the plant bearing beds elsewhere in Australia, the flora of beds probably of Jurassic age in Queensland at Talgai (Condamine River), the Darling Downs, and Rosewood West of Rockhampton, affords the closest comparison with the specimens from Western Australia.

At 3½ miles farther northward along the same road some further specimens of fossil wood were found on the hills at about 50ft. higher level [**7676**].

About 5½ miles westerly from this road is Depot Hill on the Irwin River where a shaft and bore already described were put down to a depth of 130ft., passing through 6ft. of shale according to the contractor's account (Mr. Hindley).

Numerous reed impressions and fragments of wood can be seen in the flaggy ironstone and sandstone exposed on the slopes of an escarpment facing south at about 1½ miles from this bore [**8017-9**]. There are some very fine samples of ripple marks on the sandstones about here and some remarkably fantastic ferruginous concretions to be seen, of which [**8019**], shaped like a Roman lamp, is a good example. About 4½ miles northward along the river on the west

side there is a dry well sunk in a soft coa
which there are patches of lignite [**6689-93**

Northerly from here the sandplains ris
1,400ft. and escarpments of white sandsto
10 miles but lessening in height, and bed
gradually appear in the lower portions of

North of the gully at Nagatty the top c
silicified possibly through the presence of
the soak or spring on the plain, 1½ miles
Buggallie Hill a quarry had been opened
stone of good quality with which Nangatt
[**7690**], but this may belong to the Carbo
Section 2, Plate V., Figs. 33 and 12, show t

Country near Nangatty, Upp

Fig. 33.

here. Farther north there are very few esc
gandy blue clay beds appear, but horizontal
at Wye Spring and northwards towards and
Spring. At Yanga Well, more westerly,
faulting throwing the sandstones to an angle
west.

Northwards from Alum Spring a rapi
only as far as Kockatea Spring, on account
the season (October) for finding water, so
ouring on the map north-westerly to the ra
mate only.

About 30 miles due east from Nangatt
terminate in a bold escarpment of sandstone
coast; they are capped with extensive depo
Hill is an outlier of this plateau; here the st
covering material, and several small ferrugin
and hill sides adjacent have indurated the
portions on the north side have been g

8057-8]. The configuration of the hill is shown on the sketch plan, Plate VII.

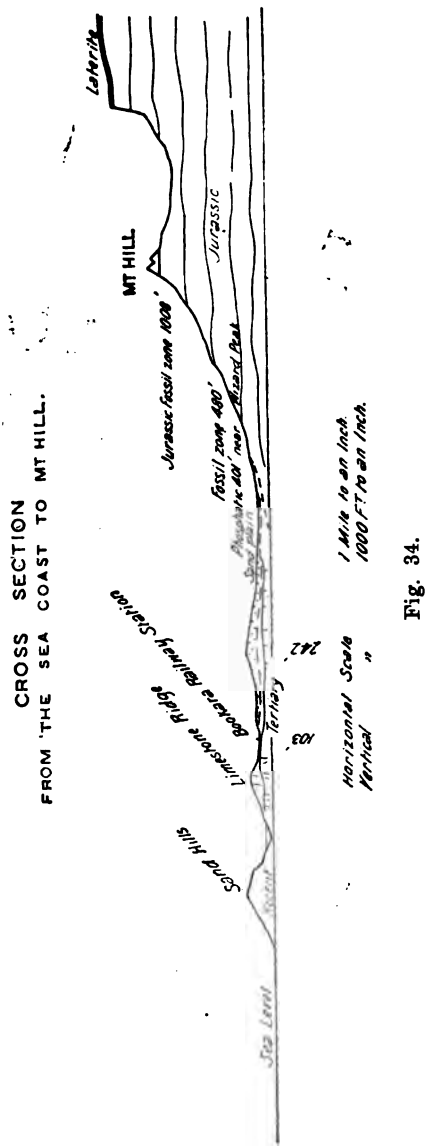


Fig. 34.

Fossil stems of a plant apparently a species of *Equisetacae*, and Palm or *Otozamite* stem scales and pieces of wood occur in the sandstones and grits of the north side.

There is a quarry at the north-western spur in a good flaggy sandstone, which has been used for building purposes at Allanooka [**8059**].

A limestone band occurs at about 100 feet below the summit of the hill and can be well seen on the fence line, 10 chains west of the summit. Here numerous Jurassic fossils occur in an excellent state of preservation. On the ridge, also, extending north from the summit, there is a fossiliferous fine-grained sandstone [**8047-8. 8055, 8062-4, 8843**]. (Figs. 35, 36).

Ten miles from Mount Hill on a radial line from north-west to north numerous outcrops of these limestone bands occur near or at the tops of the flat-topped hills skirting the Greenough valley; these bands are rich in fossils of a similar facies to that occurring at Mt. Hill [**8074**].

PHOTOS 363-6 5
QUARRY
M S 8059
M S 8056
PHOTOS 367 5/0
PHOTO 364
M S 8050-4
M S 8057-8
PHOTO 362
M S 8047-8 8062 8843 80
MT HILL
1128 JURASSIC ROCKS
M S 8063
M S 8060
M S 8049
PHOTO 360
MT HILL
SKETCH PLAN AND VIEW FROM NORT

Plate VII.

Mount Hill, from the South.
Fig. 35.

the inspection of part of this district in 1906: the same beds outcrop also about ¾ mile north of Newmarracarra Homestead [**8807**] and at the deep railway cutting about ¾ mile east of No. 1 Tank (Plate IV., Fig. 6).

Mount Hill.
Fig. 36.

The same fossiliferous band may be seen at the top of the Two Brothers, which are outlying hills of the Moresby Flat-topped range, ten miles north-westerly from Wizard Peak [**8842**], but it probably does not extend much farther north, and at Wokatherra Hill it is

evidently represented by a limonite bed with fragments of wood [8854-5].

At Loc. 1846, about 1½ miles south of Wizard Peak, at an elevation of 468 feet, ferruginous sandstones occur with green-coloured patches; these are phosphatic, containing Dufrenite, identical with that which occurs at Dandarraga, east of Moora, and described in Bulletin 26, p. 14. It was also met with at 18ft. depth in sinking a well in Loc. 1878, about 3 miles north-westerly. This shows that there is a widely extended area over which these phosphates may be found. It is interesting to find that the holders of land about this locality are very well satisfied with the yield of their crops.

The following are the particulars of the strata pierced in the deep bores put down at Dongara and Yardarino, that have been already referred to:—

DONGARA BORE.

Nature of Strata.	Thickness.	Depth.	Formation.
	ft. in.	ft. in.	
Sand	6 0	0 0	Recent
Clay	3 6	6 0	do.
Sandstone	50 6	9 6	do.
Limestone	12 0	60 0	Tertiary
Sandstone	23 0	72 0	do.
Clay	45 0	95 0	do.
Micaceous sandstone	90 0	140 0	Jurassic
Drift sand (incoherent sandstone) ..	30 0	230 0	do.
Sandstone with coal seams	45 0	260 0	do.
Carbonaceous Shale	4 0	305 0	do.
Sandstone	110 0	309 0	do.
Sandstone with veins of coal	15 4	419 0	do.
Sandstone	42 8½	434 4	do.
Sandstone with bands of carbonaceous shale	12 9	477 0½	do.
Sandstone	42 11	489 9½	do.
Grey shale	2 0	532 8½	do.
Sandstone	705 11½	534 8½	do.
Shale	9 11	1,240 8	do.
Sandstone with thin shales	124 10	1,250 7	do.
Micaceous shale	28 7	1,375 5	do.
Sandstone	88 6	1,404 0	do.
Struck water, temp. 104 degrees Flow 216,000 gals. at 1,478 feet.			
Shale	57 3	1,492 6	do.
Sandstone	100 0	1,549 9	do.
Micaceous shale	82 7	1,649 9	do.
Sandstone	379 3	1,732 4	do.
Total	2,111 7	2,111 7	

YARDARINO BORE.

Nature of Strata.	Thickness.		Depth.		Formation.
	ft.	in.	ft.	in.	
Clay and sand	53	7	0	0	Tertiary
Quartz gravel	76	5	53	7	do.
Yellow sand and ironstone bands ..	16	0	130	0	Jurassic
Quartz gravel	6	0	146	0	do.
Micaceous shale	48	0	152	0	do.
Fine white sandstone	10	0	200	0	do.
Grit	11	0	210	0	do.
Sandstone and shale	29	0	221	0	do.
Micaceous sandstone	5	0	250	0	do.
Shaley sandstone	30	0	255	0	do.
Lignite	0	6	285	0	do.
Shaley sandstone	59	6	285	6	do.
Shaley sandstone (and coal ?)	3	6	345	0	do.
Shale	16	11	348	6	do.
Sandstone and shale	15	11	365	5	do.
Sandstone, shale, and iron pyrites ..	74	8	381	4	do.
Shaley sandstone	4	0	456	0	do.
Shale and sandstone	22	0	460	0	do.
Grit, sandstone, and shale	64	7	482	0	do.
Grit, sandstone, and shale cemented in places with pyrites	126	6½	546	7	do.
Shaley sandstone	75	6	673	1½	do.
Shale	45	9½	748	7½	do.
Grit and sandstone	30	11	794	5	do.
Sandstone and grit cemented in places with iron pyrites	52	8	825	4	do.
Sandstone with occasional pyrites ..	40	6	878	0	do.
Shale and sandstone with pyrites ..	63	2	918	6	do.
Shale	23	0	981	8	do.
Sandstone with occasional pyrites ..	93	6	1,004	8	do.
Sandstone	11	0	1,098	2	do.
Sandstone with occasional pyrites ..	152	1	1,109	2	do.
Sandstone	42	10	1,261	3	do.
Shale	9	11	1,304	1	do.
Grit	87	0	1,314	0	do.
Shale	40	0	1,401	0	do.
Sandstone and grit with occasional pyrites	166	0	1,441	0	do.
Total	1,607	0	1,607	0	

When boring ceased, the water stood at 25 feet below the surface, and at this depth 2,000 gallons per hour could be pumped without lowering the level of the water. The temperature of the water was 87deg. Fahr. (See Plate V.)

Two samples of the water were submitted to the Government Analyst, Mr. E. A. Marn, at whose hands the following results in grains per gallon were obtained:

	I.	II.
Silica	·62	1·64
Iron and Alumina	·46	·28
Carbonate of Lime	4·86	2·58
Carbonate of Magnesia	3·50	6·96
Sulphate of Lime	6·60	11·36
Sulphate of Magnesia	6·72	4·96
Chloride of Magnesia	5·38	7·54
Chloride of Sodium	67·76	12 ·36
	95·90	163·68

It is of interest to note that an assay at the hands of Mr. E. S. Simpson, of the pyritous sandstone, from 913 feet, yielded a trace of gold to the ton.

Neither the Dongara nor the Yardarino bores having entered the Coal Measures, and the main object of the operations being yet unaccomplished, the necessity for definitely ascertaining the seaward extent of the Irwin River beds may be held to justify the expenditure necessary to put down another bore hole to the east, where it may be expected these strata would be met with at a relatively shallow depth, provided boring in such a locality would advance the general interests of the State, and not those of a private corporation.—Progress Report of the Geological Survey for the year 1901, p. 14.

The Dandaraga ferruginous sandstones are probably also of Jurassic age while the limestones eastward and northward from there are possibly Cretaceous. At Sheen Hill one mile north of Wizard Peak, and at the quarry ½ mile south of Mt. Fairfax, about ten miles north-westerly, the sandstone and clay is altered in places by chalcedonic infiltration to common opal of varying hardness. The name indicates the iridescent iron that coats the sandstone at the former locality; I however, did not see any iridescence in the opal [8802].

From Mt. Fairfax to Bowes River, about 24 miles, there is the high level tract of the Moresby Range already described, composed of Jurassic sandstones which forms the western side of the Chapman River valley. (Fig. 32, negatives 519, 520).

In the neighbourhood of Oakabella there are numerous and picturesque hills in the outlying patch of the same formation, of these King's Table Hill and Long Hill are conspicuous. (Figs. 37, 38; Photos. 23, 28 to 38.)

Northward of the Bowes River the Jurassic series form the western boundary of Sandy Gully to Nonga Hill and on to near Mt. Willoughby about 15 miles, and presents mostly a precipitous es-

carpment. White clay bands appear in their upper portion forming the hard surface of the plains between Nonga Hill and Garden

Long Mountain, Oakabella.

Fig. 37.

Gully and the white water to the west and south, and continues beyond the Hutt River. At Mt. Victoria and Mt. Albert opposite Lynton and the high escarpment near by to the northward, the clay

View from the summit of Long Mountain.

Fig. 38.

bands are permeated with chalcedonic infiltrations forming common opal similar to that at Sheen Hill and of colours ranging from white, brown, yellow, to purple [**8678-9, 8698-8708**]. Fig. 29.

On the eastern side of the quartz conglomerates of the Mt. Erin district horizontal beds of whitish argillaceous sandstone and dark blue clay or shales appear, succeeded by mottled clays and light coloured sandstones; their most southern outcrop is in the watercourses at Loc. 77; they were met with at the dry well in Pearse's Loc. 2828, where after 5ft. of red soil and 55ft. of mottled clay, 19ft. of dark blue shaley clay was met with; a bore was continued to a total depth of 104ft. into the same material [**7530/1**]. Two miles farther north at Forrester's Wheatgar Spring and at Durawah Spring, Reserve 89, these clays occur, the latter spring is diatomaceous as is also Corner Well, Lot 78, Mt. Erin Estate subdivision. [**7383, 8846-9**]. Between the two first-mentioned springs there are several small sulphurous springs where the conglomerate bluff occurs. A sample of earth [**8846**] from there was analysed by Mr. Simpson and found to contain the following:—

	per cent.
Pyrites, FeS_2	18·7
Melanterite, $FeSO_4, 7H_2O$	34·9
Thelite, $Fe_2(SO_4)12H_2O$	4·7
Insoluble mineral matter	1·6
Organic matter	40·1
	100·0

From the Wheatgar Spring the clays extend northwards through Loc. 92 where a well has been sunk 60ft. in blue clay yielding salt water, and through Loc. 93, where a well was sunk 130ft. in the same material without obtaining water, though a fair supply was obtained in sandstone at 20ft. depth near the western boundary. Farther northward the clays form the greater part of the Yuna area, over which there are patches of ferruginous sandstone and conglomerates, the surface of parts of these rocks is greatly silicified, at the rock hole, Loc. 3629, and around the depression extending from Loc. 3616 to 3628 [**8845**].

In Loc. 3607 the Government have sunk a well in the bottom of the main watercourse which is below the blue clay horizon; it passed through stiff white clay into white sandstone when a fair supply of good water was obtained at a depth of 49ft. [**8680-1**]. Bores were also put down at a number of places in the blue clay of the Yuna area to a depth of about 100ft., all resulting in either saline or no water being obtained.

The bed of the Irwin River, near Mondara Spring, is in a blue clay from which, during the summer, there is a white efflorescence

which has been determined in the laboratory to be a mixture of common salt with a small proportion of Epsom Salt.

Of the economic products of this Jurassic formation mention should be made of the frequent and often extensive patches of ironstone gravel and laterite (ironstone conglomerate), which latter is but a more solidified form of the gravel. [**7700, 7710, 7787, 7866, 7878, 8056, 8066, 8071-2**]. These form the best materials possible for country roads, being both inexpensive and durable; a very great advantage where the roads are chiefly over loose sand, which causes exhaustive haulage and slow travelling. The flaggy ironstone bands that frequently occur in these beds afford a rough building material: occasionally the iron is present in sufficient quantities to constitute an ore in the form of limonite and hematite [**4060, 8056, 8803, 8855**]. Ironstone concretions in these sandstones are very frequent and they are associated with thin flaggy ironstones. The concretions vary from circular balls to pipe-like stems, usually clustered two or more together. One concretion obtained south-west of Depôt Hill is shaped like a Roman lamp [**8019**]. These are formed of a shell about one-tenth of the diameter and the interior is filled with a yellowish earthy powder. The flaggy ironstones are so numerous and thick occasionally as to constitute an ironstone rock. [**4796, 7870, 7882, 8018-9, 8021-4, 8031, 8682**].

Some remarks on the origin of these deposits and of laterite are made towards the end of the section on the subject of silicification.

SPRINGS.—Infusorial earth occurs at most of the springs which flow from the sides or base of the Jurassic sandplains where they are underlaid by argillaceous sandstone and grit. These springs have very pure water and the earth is largely diatomaceous and has a peaty appearance. When dry it assumes a grey colour and can be seen under the microscope to consist of the silicious cases (frustrules) of diatoms and spongilla spicules.

The mound springs at Loc. 3179 and 3199 on the Arrowsmith River have a singular appearance forming banks and mounds three or four feet above the surrounding surface of argillaceous and siliceous grit; the spring water percolates through the entire mass of infusorial earth, and pools can be readily excavated in it and afford a permanent supply of water; the base of the mounds is 50 feet and more across, with reedy vegetation upon them. [**6656 7**]. Water sample No. 3.

Water sample No. 4 contains diatoms from the scum of these pools. No micro slides or descriptions have yet been made of these diatoms.

A good spring occurs on Reserve 973 and is known as the Arrowsmith Well, on the old track from Perth to Geraldton, see water

sample No. 2 [7578]. The spring at the
diatomaceous earth; it used formerly to ove
the two wells on and near the Railway lin
caused it to stop overflowing. [7579]. W

At Yandanooka there are two very goo
a sandstone outcrop east of the Homestead,

At Eyre Gully, about three miles south-
there are several springs and from the one
tanks at the station are supplied by gravita

Some of the houses in the township
the surplus. Fig. 39 shows the luxurious g
jacent to the Springs and the Geological S
Water Sample No. 9.

At Eyre Gully Spring, Min

Fig. 39.

The other springs at Eyre Gully are in
tion 7/160; the latter supplies a garden whi
in which a considerable variety of fruit tree
yield good returns.

Mingenew Spring, in Reserve 957, at the
is diatomaceous and the earth about it has
cutting and drying into blocks for cottage l
pose it serves well, especially when protecte
The water is pure and soft, see Water sam

Several wells have been sunk near the Railway Station without success, for the water-bearing stratum occurs higher up the hill.

The general water supply from wells in the neighbourhood is considerably charged with sodium and magnesium chlorides as at Fogarty's Well, v.d. 107ft. in Loc. 1825 sunk in a white sandstone; these ingredients cause deposits and corrosion in tanks and kettles, see Water sample No. 12. The Laboratory report states that:—

This sample owes its corrosive properties to the presence of magnesium chloride. To destroy this salt two pounds of caustic soda dissolved in a little water should be well stirred into each one thousand gallons of the water, and the sediment then allowed to settle before use. Care should be exercised not to use a greater proportion of caustic soda than indicated as excess of this salt would also cause trouble.

The water in other localities is more saline and not always good enough for stock. There are indications that the salinity of the well supply is increasing of late years, possibly through the lower stratum of water becoming exhausted and the supplies from the more saline strata of the sandplains being drawn upon, but a few years of a better rainfall may rectify this tendency.

Mondara Spring, Irwin River.

Fig. 40.

Moriary Springs in and adjacent to Loc. 257, about six miles south-east of the Strawberry Siding, are also diatomaceous; they occur near the top of the spur of the tableland there. See Water sample No. 16.

Mondara Spring is on Reserve 923, near t
affords a permanent supply of excellent water.
and Water sample No. 13.

Irwin Spring, in Loc. 803, is of similar c
and supplies the railway tanks at the siding
negative 356 [**5048**] and Water sample No. 14.

There are several springs on the east side
and Irwin valleys, but these are not diatomac
portant, both for quality and quantity, is the E
716, about 14 miles in a direct line from Ming
Rothsay road, in a white argillaceous sandsto
the rise towards the granite area at an elevatio
yield is probably under 10,000 gallons a day. S
10.

The Yungarloo Well is in gneiss about two
the same road, it also has good water, being on
between two quartz reefs a few chains apart,
wards the north, and its elevation is 1,459 feet.
No. 11.

About eleven miles south from here in M
side of the point of a high escarpment and
the top, is a permanent spring of good water, w
DeBurgh Spring.

Three and a-half miles north of Eban
Spring in Loc. 612, on a branch of the Ebano
elevation of about 950 feet, and is slightly salin

An extremely salt spring occurs in the bed
close to the south-west corner of Reserve 2297;
is "Warraga." It appears to be permanent
down stream for a long way and stock will not
sample No. 8.

There is a small but permanent spring of g
third of a mile north of the coal drive and on
watercourse, where it intersects the cliffs. It is
potable water for many miles around. Its nati
it is also locally known as the "Doghole Sprin
serve here.

Twelve miles south-westerly from here is
in a depression in the high level plain on the w
valley. The rock is argillaceous sandstone sin
quarry [**7690**]. The pool is evidently only a so
manent supply of good water. See Water sa

is also a spring in the face of the escarpment about two miles south easterly in Loc. 1167, the site of the original homestead.

Durawah Spring is in Reserve 89, six miles south-easterly from Mt. Erin; it is near the west margin of the quartz conglomerate ridge and has diatomaceous earth resting upon white clay [**8847-8**]. See water sample No. 17.

The spring in Loc. 42, Narra Tarra, is about two miles south-westerly from Fossil Hill and is on the boundary of the Jurassic series; it is diatomaceous [**8818**]. See negatives 517 and water sample No. 18.

Two miles easterly from here is the so-called Higgetty Spring; it is, however, only a soak in a valley which trends northerly. There is here a claypan at the north end of a granite outcrop; it was dry at the time of my visit in March, 1909.

The sample of water from Willow Gully, near the mouth of the Bowes River, Loc. 428, is from the well in the garden of the homestead and is near the boundary of the coastal limestone; see water sample No. 19.

No supply of water was struck in the bore of 500 feet, v.d., put down by the Midland Railway Company north of Mount Scratch, nor in the bores of 913ft. and 736ft. put down near Mingenew already referred to, nor in the Depot Hill Coal Prospecting Sydicate's bore of 278ft.

The deep bore put down by the Government at Dongara struck salt water at 1,478 feet and at the total depth it was 216,000 gallons in 24 hours, the temperature being 104 degrees. The water ran from the bore for four years until it became choked by rubbish. At a depth of 149 feet water was met with in a bed of sandstone, and stood at 17 feet from the surface. On further boring to a depth of 935 feet the water rose within 2ft. 6in. of the surface. When operations had reached 1,023 feet in a coarse grey sandstone, the water rose to the surface. The first overflowing supply was encountered in a micaceous sandstone at a depth of 1,259 feet 7 inches, the yield being 128 gallons per hour. This flow increased to 240 gallons per hour at a depth of 1,327 ft., the water being obtained from a bed of micaceous sandstone. A supply of fresh water flowing at the rate of 3,600 gallons per hour, was met with at 1,384 feet. The water, which is said to have been of a dark colour, flowed from a micaceous shale and issued with a temperature of 98 degrees and rose 22 feet above the surface [**5538**].

The Yardarino bore already described yielded artesian water, a flow of 589,000 gallons in 24 hours being struck at the total depth of 1,607 feet; this flow was not maintained however, and after a few years it ceased to overflow. The bore site being about 16 feet

above the river bed, Mr. Phillips, the owner of the adjacent ground, put in a line of pipes from the bore to the river bed at the level of the latter and secured a permanent flow into the watercourse for stock purposes. The water has a temperature of 86deg. and is saline. See water sample No. 20 [**3438**].

Nangatty Spring is a large pool around which there are several wells and affords a permanent supply of fresh water, but it is probably only a soak; there is evidently a soakage from here towards the gully in the escarpment 1½ miles to the south-east. Several wells have been put down for some miles northwards from here, yielding good water, but 1½ miles north-east from Nangatty Spring there is a pool with very salt water in which was noticed a luxuriant growth of a slender bright green seaweed-like plant.

At Allanooka, Loc. 809, about ten miles due east of Bookara, there is a strong spring of very good water, in a valley at the foot of the high Jurassic escarpment, where there is an extensive clay-pan. It is diatomaceous [**8061, 8065**].

Regarding the water generally, Mr. Simpson remarks that there is a prevalence of nitrates in the water north of Mingenew, which fact is interesting since it is probable that the same cause which brought this about has been largely responsible also for the presence of nitrogenous deposits in the caves of the district south of Mingenew at Jankara, Jingemia, and the Nambung valley. This subject is discussed at considerable length by Mr. C. R. Van Hise in his great "Treatise on Metamorphism," forming Monograph 47 of the U.S. Geological Survey. On p. 542 he writes:—

> In the arid regions not only are the relatively insoluble compounds precipitated in the belt of weathering, but the readily soluble compounds may likewise be thrown down, such as the salts of the alkalies and alkaline earths. These elements may be combined with any of the acids which exist in the soils. Thus there may be precipitates of such soluble salts as the alkaline carbonates, and even the alkaline chlorides and nitrates. The more abundant salts precipitated are sodium, potassium, calcium and magnesium carbonates, sulphates and chlorides. Nitrates and borates of the bases mentioned are also locally abundant. In any given case the bases and acids unite in such a manner as to produce the most insoluble compounds . . . . . The compounds are likely to be precipitated in the openings of the rocks, where evaporation may occur. Such openings are, of course, by far the most abundant in the soils at and near the surface, and decrease in abundance with depth, but below the soils are found joint cracks, bedding partings, caves, etc., and in such openings deposits of the various compounds are built up. While in these openings the precipitation is largely dependent upon the abundance of the solutions and their evaporation, and also upon the abundance of the various salts and their evaporation, and also upon the abundance of the various salts and their relative solubilities; in exceptional cases the reactions may not be simple chemical ones, but be largely or wholly dependent upon animal life. This is illustrated by certain caves where abundant phosphates and nitrates are attributed to the excrements of bats. But as already said, the preponderant precipitates of the belt of weathering form in the soil.

TABLE

nt Waters from

11. Yungarloo Spring. Block 2016. 203c.	20. Yardarino Bore.		Dongarra Bore, 6th Oct., 1899, Water from 1,400ft. level.
ly.	15th Feb., 1908. 1534.	17th June, 1901.	
Nil	*Nil*	not det.	not det.
Nil	*Nil*	not det.	not det.
..	not det.	not det.	not det.
·0543	·1789	·0969	1·6498
..	·0317	·0077	·2244
·0013	*Nil*	·0077	not det.
..	..	..	..
·0019	*Nil*	not det.	not det.
·0036	·0063	·0096	·0024
..	·0170	·0094	·1765
..	..	..	..
..	..	..	..
·0029	..	·0050	·1017
·0023	·0052	·0069	·0291
·0017	trace	trace	trace
·0101	*Nil*	not det.	not det.
·0002	trace	not det.	not det.
trace	*Nil*	not det.	not det.
·0005	·0007	·0006	·0021
·0124	·0014	·0009	not det.
·0912	·2412	·1370	2·1860
not det.	not det.	not det.	not det.
Nil	*Nil*	*Nil*	*Nil*
str. trace	*Nil*	*Nil*	*Nil*
Nil	*Nil*	*Nil*	*Nil*
..	..	1,607 feet	2,111 feet
..	..	86°	104°
6·1			
Moderately pure, soft.	Extract from P.W. Report for 1st half-year, 1906, p. 36–37.		

SILICIFICATION.—The extent to which the high level surfaces of the strata have been silicified is very remarkable. This is most noticeable along the tops of the eastern escarpment of the beds of Jurassic age of the Greenbrook and Irwin valleys, where the friable sandstone has weathered away leaving cliffs protected at the top by a quartzite capping [**7597, 7599, 7675, 7793, 7862-5**]. Blocks derived from the breaking down of these cappings are strewn all over the valleys [**7806, 7847**]. A closer examination of the capping shows it to have a matrix of glassy or amorphous quartz evenly distributed throughout its mass, the result of the deposition of silica in solution probably extending over great periods of time. The depths to which this silicification extends varies from 3 to 20 feet, but at times it exceeds double that depth as at Mt. Hill and at Coorow Cave.

The same general features of flat-topped hills with precipitous sides around their upper margins are produced where there is a capping formed of laterite or concretionary ironstone, but in the latter case it is usually of less thickness and may be then mostly a residuary deposit from the subaerial denudation of the country, but in others it is probably largely due to a chemical change or iron carbonates in the soil or in the component parts of the rock, or in some cases may be due to extraneous origin as in the proximity of ferruginous veins and lodes as at Mt. Hill [**8060**] and at the low hills 1½ miles east of Mingenew.

In a few instances quartzite cappings were observed in valleys as at the side of a watercourse on the east side of the railway about four miles from Arrino resting on argillaceous sandstone, which is probably of Carboniferous age. There were here also a few blocks of silicified wood lying on the surface of the ground [**7602-4**].

There does not appear to be any trace locally of any sites where thermal springs have once existed and moreover the wide spread and also scattered patches of cappings are against that mode of origin as is also their flat-lying character; although the silicification is mostly seen in the sandstones, the argillaceous sandstones also have frequently these cappings as at one mile east of Arrino Railway Station [**7601**] and at Gnoolowa Hill, where it is about four feet thick [**7693**]. Specimen [**7691**] shows the base of the alteration zone of somewhat similar material at the high bluff about two miles south-west of Nangatty.

Another phase of silicification is to be found in the silicified blocks of claystone (porcellanite) that are frequently to be met with in the river beds 3½ miles east of Nangatty, apparently freshly washed out of the clay of the river bank, which would indicate that the chemical alteration had taken place while *in situ*, not recently but during the period that has elapsed since the Carboniferous deposits were formed [**7845-6, 7849, 7854**]. Sample [**8057**] is from the top of an outlying spur of Mt. Hill, composed of "silicified grit," where great depth of silicification has taken place. See Appendix No. 1.

A silicification of cave guano is mentioned in the portion treating of the recent period, and the occurrence of silicified wood at Arrino has already been mentioned [**7603**].

These processes of modification of rock characters are the reverse of the more general workings of changes by oxidation, carbonation, hydration, and solution; they have been brought about by deoxidation, silicification, dehydration, and deposition, and convert the zone of weathering into one of cementation. The arid conditions prevailing during the greater part of the year and the heat of the sun's rays probably have caused long periods when evaporation is the predominant feature causing the deposition of substances held in solution by surface water. Changes of temperature and the alternation of periods of humidity and dryness would also induce a great amount of circulation of water in the porous soil and rock which would be favourable to the deposition of materials held in solution. Mr. C. R. Van Hise in his work on Metamorphism already alluded to discusses this subject very thoroughly, and on p. 204 he thus defines the terms used:—

Carbonation is the union of carbonic acid and base, or the substitution of carbonic acid for another combined acid in either case producing carbonates. The oxide with which carbonic acid most frequently unites is iron oxide. Carbonic acid may replace any of the other ternary rock-forming acids, including silicic, titanic, and phosphoric, and thus become united with any of the important bases. The carbonation of the silicates is of fundamental importance, the carbonation of the titanates and phosphates is unimportant.

De-carbonation is the separation of carbonic acid from a base without the addition of other compounds or with the substitution of another acid for the carbonic, the most frequent substituted acid is silicic.

Silication is the union of silicic acid and base, or the substitution of silicic acid for a combined acid, in either case producing silicates. The only important oxide with which silicic acid unites as a rock-forming constituent is iron oxide. Silicic acid may replace carbonic, titanic, or phosphoric acid, thus becoming united with any of the bases with which it can combine.

Desilication is the separation of silicic acid and bases without the addition of other compounds or with the substitution of another acid for the silicific acid. The most frequent acid substituted is carbonic.

Silicification involves the addition of silica without union with bases. The added silica may or may not replace other compounds.

Desilicification involves the substraction of free silica. The subtracted silica may or may not be replaced by other compounds.

On p. 479 he says:—

The process of carbonation just considered is one of paramount importance in the belt of weathering. Although the process is not so extensive as hydration, if one were to pick out a single chemical process especially characteristic of this belt and of great significance in geology it would be carbonation.

He then goes on to discuss the subject on p. 546:—

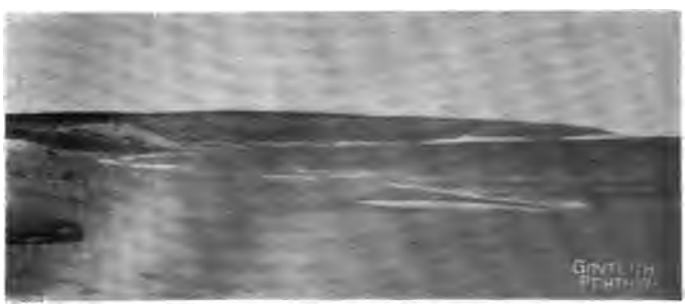
Many sandstones which have long been exposed to the weather have a thin outer layer or crust of quartzite. Sections of such material show that it is a true cementation quartzite. Case-hardening also occurs in many kinds of rocks, for instance granite. In the production of case-hardening the waters have penetrated to a greater or less depth, and

through capillarity have been brought back to the surface as a result of drying of the outer surface. During the journey the water silica is dissolved, probably mainly in the colloidal form. This H Si O is doubtless largely that liberated from the silicates during the process of carbonation. Probably the solutions do dissolve some silica from chert and quartz, and bring it to the surface, but the amount of this is probably small compared with that transported in the colloidal form. It therefore appears that the process of surface cementation, so far as the cement is silica, is a correlative of the process of carbonation.

Very near the outer surface of the rock the water evaporates, the silica is dehydrated, and quartz is deposited. In this case chemical change takes place. The silica is thrown down in a very difficultly soluble form, so that even in humid regions the falling water is unable to dissolve the quartz and carry it downward. This process may continue until the sandstone which may be loose or almost incoherent below the surface, is a quartzite at the surface. The case-hardened layer may be a mere outer film, but a fraction of a centimetre in thickness, perhaps one-half to one-fourth of a centimetre. In other cases the case-hardening may extend to a depth of a centimetre or even several centimetres. Ordinarily the maximum induration is at the surface, and the transitions between the indurated and soft parts of the rocks are somewhat rapid. This fact gives positive evidence that evaporation and consequent deposition are at a maximum at the surface.

In regard to the ferruginous deposits on the surface he says, on p. 548:—

Surface induration, while most common as the result of the deposition of silica, is not limited to this compound. The upward moving solutions carried by molecular attraction may, under favourable circumstances, contain iron salts in solution. When the solutions approach the surface evaporation takes place, and the iron salts are thrown down, usually as limonite or hematite. If precipitated as limonite, this compound may be later dehydrated and hematite be formed. Where the iron salts are transported as carbonate, oxidation takes place at the time of precipitation. While it is not necessary to suppose that the iron is always transported as carbonate, since limonite and hematite are so



Limestone Range, South of the mouth of the Hutt River.

Fig. 41.

insoluble it is natural to suppose that in most cases the iron is transported in some other form than oxide, and is chemically changed when precipitated. By the above processes we have surface induration due to iron oxide cement.

In regard to carbonation, he says, on p. 476:—

> The reaction of carbon dioxide upon the silicates and other compounds in a soil there may be present both sedimentary and secondary carbonates. Now it has been shown experimentally by Bischof that the alkaline carbonates are capable of decomposing the silicates at ordinary temperatures and pressures. A great variety of silicates were thus decomposed, the alkaline silicates and carbonates of sodium, potassium, calcium, magnesium, and iron were formed. Not only do the alkaline carbonates decompose silicates in the belt of weathering, but other carbonates accomplish the same result.

The above extracts elucidate the occurrence of both silicification in the form of quartzite cappings and also of ironstone gravel and laterite (or ironstone conglomerate), both of which forms of surface changes are so noticeable in this district.

TERTIARY STRATA.

Bordering the coast there are Tertiary beds resting chiefly upon the eroded surface of the Jurassic formation just described, but also occasionally resting upon the crystalline rocks. These Tertiary beds are limestone and sandy strata, the former attain in places an elevation of 800 feet, so that they must have been deposited before the depth over this part of the then sea bottom had been reduced to 1,000 feet. The elevation of the land was probably a very

Limestone Hills from the bed of the Bowes River.

Fig. 42.

gradual one after the Jurassic period and was probably followed by a depression after or towards the close of this period, but of the latter no proofs were noticed during this survey.

Along the coast with occasional short intervals this limestone forms a prominent ridge of varying elevation. Southward of Dongara it is a somewhat sandy limestone, frequently cavernous near the surface, and it is in these caves that the so-called guano deposits occur that in the valley of the Nambung, near the coast due west of Moora. Plate, Figs. 41-46 and negatives 522, 524. The limestone north of Dongara is usually very dense and hard [**8043, 8076, 8864**].

The basal beds can be seen covering ferruginous sandstone of Jurassic age in the valley of the Hutt River, near Lynton, and on granite in places south of the Bowes River [**8838, 8867**]. The limestone is frequently foraminiferal as at Irwin River and Chapman River bridges [**8032-3**] and at Loc. 1714, eight miles south of Don-

Cliff at Yardarino, showing current bedding in sandy limestone.

Fig. 43.

gara, fossils are however not common, but what is apparently a species of *Terebratula* was found in the capping of a small hill at Yardarino at an elevation of 490 feet [**8035-6**]; some fossil shells were met with in the limestone at the well in the sanitary depôt at Dongara [**8864**] and in the railway cutting about a mile north of Bokara railway station [**8044-5**]. It is, however, possible that the latter may be only of recent age. A good section of sandy limestone showing current bedding and containing a few corals occurs at Yardarino near the school house, lot 13 [**8037**], Fig. 43. A good deal of limestone and lime has been despatched from White Peak for commercial purposes, and also from Crowther, a sample of the latter

was analysed by the Government Analys
sult:—

Loss on ignition	..
Carbonic Acid	..
Lime as Calcium Oxide ..	..
Silica	..
Undetermined matter ..	..

Mouth of the Irwin River
Fig. 44.

In both places the limestone was coll
face or from shallow excavations.

At Port Gregory, Lynton, the reef
limestone ledge dipping 3deg. west and so
ing up to 10ft. long of the same mate
bivalve shells; these blocks are evidently
superincumbent stratum that has disappe
action of the sea waves.

The undulating flat extending between
man Rivers is apparently the same age
marly patches which are scattered over
more than about 30 feet deep and appear
strata that surround them. The new l
Crowther passed through one of these.

Rudd Gully is interesting on account
it evidently was at one time an important
Turner Flat near Bootenal Road.

To this period probably also belongs
nous soil in the valleys of the Bowes, Ch
which has resulted from the wearing do
The limited time at my disposal preclu

such deposits separate from the Jurassic. It consists mostly of a semi-compact ferruginous sand with a slight admixture of clay. In the Chapman valley the bed rock being partly crystalline the deposit can be more readily distinguished than in the others, and it can be seen to extend up that valley at the Chapman Agricultural area to an elevation of over 600 feet. A depth of twenty feet is of common occurrence for these deposits.

The depressions in the surface of the plains which give rise to clay pans are largely solution hollows, and the caves are solution channels. There is a similar hollow or valley at Bookara at the south end of the outer flat; it is 1½ miles long and became filled with the flood water of the Greenough River in the year 1872 and remained so for several years and gradually evaporated. There is a funnel-shaped hole in the limestone near the south end into which it is said the water drained when it was up to the level of the hole. The height of the water reached to the top of the telegraph poles at the road. This is spoken of as the great flood; it was the more

Inaccessible Cave North of Stockyard Gully Cave.

Fig. 45.

remarkable as the water came down from the interior without there being any rainfall on the coast. Both the south end of the inner flat at Mr. Sewell's Mt. Hill Homestead, Loc. 1424, and the outer flat at Stokes House, Loc. 895, are 8 or 9 feet lower than the flat about three miles northerly and they also impounded the flood water there at the time of this great flood.

Only a brief visit was made to the caves south of the Arrowsmith River; the route taken was from Dongara southwards along the coast road, and the farthest point visited was the Three Springs Reserve 970, about 50 miles south.

During the journey the first indication of the cavernous nature of the calcareous beds was the hollow sound when passing along the track on the flat near the well in Loc. 1823, about 18 miles south of

back of the cave which deepens somewhat there. Numerous bones of small animals and birds were noticed on the ledges of the floor [**8861**].

About one mile south of this cave there is an inaccessible cave (Fig. 45) negatives 527, 530, and within a mile south from there is the Stock Yard Gully, into which the water from the gully runs in winter time and occasionally fills it and then gradually soaks away. This cave is of large dimensions; the funnel entrance is about 100ft. diameter and 50ft. deep and the cave is about the same width and 40ft. high; there is a descent of about 25ft. or more to the bottom of the cave from the funnel hole. The bottom of this cave is very rocky through the stream carrying away all small particles (Fig. 47). The subterranean drainage from this cave is said to go to the salt lakes about 7 miles distant, which extend along the coast for about 15 miles. I was informed that there are places off this coast where fresh water can be obtained from the surface of the sea.

Another cave of smaller dimensions occurs about a quarter of a mile easterly from Three Springs, about three miles farther south. The entrance is a small funnel hole, perpendicularly, which widens out after about 20ft. depth.

PLEISTOCENE AND RECENT STRATA.

The strata of the recent period include the sand dunes and sandy and coralline limestone along the coast and to some extent the sand of the sand plains through the disintegration of the various rocks, the alluvium of the rivers, the gravels and erratic blocks and evidences of snow glaciation, the gypsum, guano and salt deposits.

The sand dunes form a noticeable feature on the coast and attain at least 300ft. elevation near the Greenough River, and extend a distance of four miles inland at Dongara, but they are mostly confined to a strip of half a mile in width along the coast. The sandy and coralline limestone forms the low cliff and reefs and can be seen at Leander Point and the entrance to the Irwin and Greenough rivers and probably at Point Moore, but the latter were inaccessible at the time of my visit, through high tides. At Leander Point caverns of grottos have been worn out by the action of the waves and the coral structure stands out in bold relief [**8041-2**], negatives 358-9, 369-71. At Gallin's quarry near the cemetery at Dongara there are recent shell beds, 25ft. above the sea-level [**8038-40**], Fig. 44. There has plainly been recent rising of the land, which has brought these corals up from the depth that is necessary for them to live below the surface of the sea. The top of the coral ledge here appears to be about eight feet above the mean sea-level. It is highly desirable that some substantial masonry pillars be constructed at such localities as this, to record the existing position of the land in relation to the mean sea-level in order to afford evidence in future years of any changes which may be taking

place. Such pillars have been erected in parts of New Zealand many years ago and an elevation of several feet has already been proved by means of them.

The Western Gorge, Mount Hill, showing bed and terminal moraines. Fig. 48.

Small blocks of pumice up to 4 or 5 inches diameter are frequently found at the entrance to the Bowes and Hutt Rivers and along the coast about there [8837]; these have been cast up by the sea waves, having apparently drifted from the volcanic regions in the neighbourhood of Sunda, which is the nearest scene of volcanic disturbance, where this material has recently been ejected. At the time of the last great eruption a few years ago the surface of the sea was covered in places with floating pumice and vessels had to plough their way through it, and it scored and scraped their sides.

The alluvium of the rivers has only been defined in special cases, such as the Greenough River flats and some of the valleys in the Northampton district, the latter being shown on the previously published map of that part. The Chapman River alluvial includes some brick clays that are being used for brickmaking near the mouth of the river. It has already been pointed out that much of the soil of the valleys and plains may have an older origin than the

recent period and may be as much due to Tertiary weathering as to recent date. Gravel beds occur occasionally in the river beds and valleys, and evidence was also observed of the existence of older high level gravels; a patch of the latter was seen at the top of the sandstone plateau, at the head of the breakaway in which the De Burgh Spring is situated; this gravel contains worn and smoothed blocks, nearly six feet long, similar to those that may be seen scattered in lower parts of the valleys and which are evidently derived from the quartzites which are *in situ* near Billeranga Well, 10 miles to the north-east. These however may be rearranged material of the Carboniferous age glaciation already referred to. This brings the subject of snow glaciation under consideration to account for the distribution of these blocks, and certain moraine accumulations at Mt. Hill and, in less plain degree, some other places also.

These deposits at Mt. Hill consist of moraine-like lines of rocks arranged along the beds of the two gullies in the northern portion and heaps like terminal moraines (Figs. 48-50). The blocks of rocks composing the heaps are of local origin and do not show any polishing or grooving, but are collected into these rows in a trough-

The upper portion of the Eastern Moraine, Mount Hill.

Fig. 49.

like manner, with a continuous lateral ridge like ordinary glacial moraines. Their regularity is far greater than would result from an adventitious gathering of fallen rocks, and they have not been

arranged by water, for the blocks are not sorted to size in beds nor are they mixed with gravel or sand. The bed of the gully is wholly filled by these rocks and there are numerous conical pits up to five feet diameter at the top and ranging to about three feet deep. The only explanation that appears to be able to account for these deposits is that of a snow glaciation, which was sufficiently solid to transport blocks of stone but not to groove them.

There are appearances elsewhere in the granite area between the Greenough and Chapman Rivers which may be interpreted similarly to these instances at Mt. Hill, such as a single heap of stones arranged in a line along a curve of a gully near where diorite or other hard rocks show through the surface soil, and I have seen

The bed of the Eastern Moraine, Mount Hill.

Fig. 50.

very similar accumulations of rocks without earthy intermixture in the Canning River valley, and doubtless many other instances could be found if they were sought for.

ECONOMIC PRODUCTS.

The INFUSORIAL OR DIATOMACEOUS DEPOSITS of many of the springs in the sandstone area near the coast have been found useful as a cheap local building material when sundried in moulded blocks.

GYPSUM has been found in the dry bed of a lake at Cliffy Head, 20 miles south of Dongara [5055], and four leases of 20 acres each have been surveyed there. The locality was not visited, but the deposit is stated to be about 4ft. deep. It is in the form of a fine

crystalline powder associated with the shells of Cardium unedo (a living species). A bulk sample was analysed by Mr. Simpson in

The upper portion of the Western Moraine, Mount Hill.

Fig. 51.

1903 with the following result (see Progress Report of the Geological Survey, 1903, p. 28):—

	per cent.
Lime CaO	32·18
Magnesia, MgO	·39
Soda, Na_2O	·87
Potash, K_2O	·13
Iron Oxide, Fe_2O .. .. ..)	·11
Alumina, Al_2O_3 .. ..)	
Sulphuric Anhydride, SO_3	41·75
Carbonic Anhydride, CO_2	2·46
Chlorine, Cl	·57
Insoluble { Silica, SiO_2	1·39
{ Alumina, Al_2O_3	·35
Combined water, H_2O	16·99
Hygroscopic water, H_2O	·84
Organic matter	2·68
	100·71
Less oxygen equivalent of chlorine	·13
	100·58

The insoluble matter contained 1.39 silica. The soluble matter 70.98 per cent. calcium sulphate and 5.27 calcium carbonate. Mr. Knowler, the lessee, charged 35s. a ton f.o.b. Dongara for this material. This price was, however, more than double that at which gypsum can be obtained in Perth from Port Adelaide.

On the sandy beach at the south end of the low cliff at Leander Point a large quantity of seaweed collects at some periods of the year, and the decomposition of this weed appears to give out a sulphurous odour and also causes a sulphurous deposit in the sand; a sample of this has been analysed in the Survey Laboratory and yielded the following:—

Free Sulphur	14.24	per cent.
Sulphur in combination (Gypsum)	.39	„
Total Sulphur	14.63	„

A similar odour was noticed in a less degree at the north side of Point Moore, where there was a smaller accumulation of seaweed.

CAVE GUANO, or phosphatic material, was seen in considerable quantity at the Jankara cave in the form of a powdery substance of a yellowish tint. This formed a heap on the floor of the farthest end of the cave. Samples from the Jankara cave have been analysed by Mr. Simpson [**8859-60, 8871**], who reports:—

	8859.	8860.
	per cent.	per cent.
CaO	24·16	6·84
K_2O (soluble in acid)	·61	·12
P_2O_5	23·50	3·16
N	1·69	·79
Insoluble	19·53	74·39

These samples are the same kind of material termed dirt beds by Mr. S. Goczel in a paper read before a conference of delegates from Agricultural Societies held on August 26th and 27th, 1908, and entitled "The Dirt Bed Phosphates of Western Australia." He considers that these dirt beds were formed at the same time as the calcareous sandstone of the caves, and says:—

> The dirt beds within the calcareous sandstone formation have often been the initiatory cause for the formation of caves and underground water channels. Dirt bed faces are often exposed in such caves, and natural concentration of phosphatic material takes place during cave growth.

In regard to the subject generally, it would seem that the fine powdery form in which most of the cave earths are found is more indicative of the partly chemical origin of the material than to its being due only to animal origin; this matter has been touched upon already in the section dealing with springs. This conclusion makes the subject of more than local importance.

The guano deposits in the Jingemia cave were briefly alluded to in the Geological Report of the Geological Survey for 1907, p. 9: it is there stated:—

> . . . the cavity itself cannot be observed until the range is climbed, and not even then until the edge is reached, when it presents a striking feature, having a sheer face 70 feet in depth upon the southern side, whilst to the northward is a semi-circular rough steep slope, whilst a cavern 25 feet in height by 62 feet deep and 20 feet across pierces the vertical southern face from the bottom of the pit; the whole may be roughly described as a theatre-shaped hollow, the cavern representing the stage and the semi-circular sloping sides the auditorium. . . . . In the main cavern the floor is level and covered by a soft powdery deposit of guano; this has been sunk in for a depth of 20 feet to the bottom. . . . . These caves in all probability owe their origin to subsidence caused by the collapse of caverns in underlying limestones which have been dissolved by percolating waters.

Bishop's Hole, another cave, about five miles south of Jingemia, was also visited and described.

Four samples of guano were analysed by the Mineralogist and Assayer and gave an approximate value of 10s., 33s., 189s., and 363s. per ton.

Another report was made by the State Mining Engineer which was published in the *West Australian* of 9th April, 1908.

Mr. H. Rowley also reported on the deposits, and it appeared in the *Morning Herald* of 11th of February, 1908. He stated that he considered—

> . . . the Jingemia deposits to consist principally of two classes of fertilising material, one of which is nitrogenous and phosphatic guano whilst the other is a secondary accumulation of silicified guano which has formed a phosphatic rock and in which there is almost no nitrogenous value. This rock must be finely ground for commercial purposes, its main value being in its phosphates.

Salt is a rather too plentiful mineral throughout the district under review; it occurs both in the soil and in the water of the springs and wells, and interferes greatly with the capacity of the country for all occupation purposes. It can be seen efflorescing from the clays and sandstones, and in places it is this that makes so many of the deep permanent pools of the river saline.

The shallow depressions that form a chain of lakes known as the Yarra Yarra lakes, near Carnamah, form natural evaporation basins for the deposit of salt, and immense quantities of this material are available there, as the lakes are dry during the greater part of the year. A lease of 2,000 acres was granted in February last to Messrs. F. J. Mann and A. E. Cockram for the purpose of collecting salt near the west side of the railway line.

At the Hutt Lagoon, Lynton, the greatest deposit of salt occurs, and Messrs. Fallowfield and Co., of Geraldton, have had a lease of 1,000 acres of the lagoon bed for about two years: the term of the lease is 21 years. The works are near the south side of the old entrance from the sea, and a small jetty has been constructed in Port Gregory, and a tram line crosses the sand ridge from there to

the salt-gathering operations on the lease. The salt forms a cake that is semi-transparent and is up to three inches in thickness, which is hoed up by workmen and placed in trucks and stored in the stack shown in Figs. 52 and 53, when it is conveyed in bags to

Collecting Salt, Fallowfield's Works, Hutt Lagoon.

Fig. 52.

Salt Stack, Fallowfield's Works, Hutt Lagoon.

Fig. 53.

Geraldton by steamer for refining. Thirteen workmen were engaged in the operation here at the time of my visit, and I was informed that twelve more are engaged in the other operations. The firm have gathered 1,000 tons of the salt, so that the undertaking may be said to have passed the trial stage. It is remarkable that after the surface of salt has been removed it makes again from below in a few weeks time and can then be gathered afresh.

The salt occurs both as a solid translucent cake and in a filamentous state, according as to whether the water was calm or ripply

when evaporating. A sample [8839] has been analysed by Mr. E. S. Simpson with the following result:—

Sodium chloride	95.07
Magnesium chloride	.14
Magnesium sulphate	.08
Calcium sulphate	.17
Insoluble in water	.04
	100.00

This sample of crude material, he remarks, is a pure salt suitable for all uses to which coarse salt is put. To make the best dry table salt it would be necessary to purify it by solution and recrystallization.

The weathering of the rocks in the steep faces of the sandstone hills has left many small caves and rock shelters which the aboriginals have inhabited at times and still do when they find their work as boundary riders or shepherds enables them to do so, but there are no longer any wandering tribes, and only occasionally individuals are to be seen.

The caves of this character have a smooth grassy slope stretching from the cave entrance, constituting the "kitchen midden," and composed of ashes, charcoal, sand and debris of their meals. The floor of the cave is composed of an accumulation of similar materials, the roof and walls are blackened with the smoke of fires, and where any part of the cave presented smooth and hard surfaces, they have been decorated with the sign manual of the inmates in the shape of stencilled paintings of hands, weapons, etc., with a paint composed of clay, fat, and wilgie, applied around the object delineated by means of the top of a bashed stick forming a rough brush. These signs are often of significance to the blacks and deserve to be respected and kept free from obliteration by thoughtless persons, as mementoes of a fast disappearing race.

The SANDPLAINS which constitute so large a portion of the area under review are almost wholly treeless, having only small scrub from 2 to 4 feet high with a little tussocky grass and occasional clumps of scrub called wye thickets, which are a dwarfed growth of eucalyptus, with a few white gums and Christmas trees (*Eucalyptus redunca and Nuytsia floribunda*) and grass trees, and more rarely the cypress pine (*Callibris robusta*), while fringing the watercourses there is usually a row of white and flooded gums (*E. rudes* or Edecipiens) and shea oaks (Casuarina). These sandy tracts, although having such a forbidding appearance, prove good feeding ground for stock when the grass in the valleys has withered up, for the animals browse off the young shoots of the small scrub. The chief drawback lies in the presence in certain areas (mostly the higher lying tracts, where there is ironstone gravel) of certain poison plants, of which the "York Road" (*Gastrolobium calycinum*) is the

principal species. Pastoralists frequently fence off such tracts, for the plant is deadly to sheep and cattle. From near Nonga to Lynton is the worst infested tract that I have ever seen, and it has proved a serious drawback to the pastoralists there. In the Upper Irwin district there are some fine belts of salmon gum (*E. salmonophloia*) and other timber of large growth.

The granite districts have the usual moderate sized vegetation of the coast, consisting of gum and jam trees (*Acacia acuminata*), except on the high level tracts where it is mostly open plain country.

From the accounts of old residents the jam trees have greatly increased in number and size within their memory, and now afford a good supply of timber of sufficient size for fencing purposes; they attribute this growth to the absence of periodical firing of the scrub by the aboriginals, which they say used to be made.

The following observations for dip and variation of the magnetic compass were made:—

At Mount Melara, near junction of Ebano Creek with Lockier River, 23deg. south, 2½deg. west.

At Irwin Siding, 24.62deg. south, 3deg. west.

At Billeranga, Loc. 3084, 25deg. south, 5deg. west.

At Northampton, 24¼deg. south, 2½deg. west.

BRIEF NOTES UPON SOME IRWIN RIVER ROCKS.

(By Messrs. E. S. Simpson and L. Glauert.)

Group I.—**Granites, etc., practically free from inclusions of accessory secondary minerals.**

[7791] Sec. 999. GRANITE. From well at Stockyard, Carynginia Gully.

This is a light grey granitic rock showing much pink and white felspar as well as a considerable amount of quartz. A little biotite can also be distinguished. With the microscope we recognise much quartz by its clear nature, its irregular outline, and its strings of inclusions. We have two felspars, one of which is seen at once to be microcline, for it has the characteristic microcline twinning splendidly developed. The other one I take to be orthoclase. Biotite and hornblende are also present as well as the following accessories:—

Ilmenite (leucoxene) and an isotropic mineral (sodalite?).

This granite greatly resembles the specimen previously obtained from Parkerville by the Mineralogist and Assayer [8574, 8575, etc.].

The succeeding three rocks are also derived from the same magma [7653, 7855, 7856].

[7703] Sec. 991. GNEISSIC GRANITE. From well about 2^3_4 miles south of Kockatea Spring.

This is a metamorphosed example of the preceding rock [7791]. In it we see the constituent minerals arranged in gneissic bands and notice the appearance of a vein of epidote. Under the microscope we see the identical mineral observed in [7791]. They show inclinations

of adopting a banded structure, and in the course of their alteration give rise to new minerals, epidote being the most abundant.

[7653] Sec. 992. FINE-GRAINED GNEISSIC GRANITE. From 1 mile east of Ebano Spring.

This is a fine grained rock almost resembling a ceratophyre in structure. Its colour is a greenish light grey and its texture very uniform. It is seen to be composed of fairly small crystals of clear colourless quartz with many inclusions. Orthoclase and plagioclase felspar, the latter often showing repeated twinning, and albite lamellation and a few flakes of brown biotite. In places these minerals are surrounded by a matrix of very small crystals of quartz and felspar, in this way resembling ceratophyres. Iron ores and chloritic material are the chief accessories and alteration products.

[7856] Sec. 993. FINE-GRAINED GNEISSIC GRANITE. From the head of Woolagate Creek.

This rock is very similar to [7653], but differs from it in being of a rather coarser texture. The microscope shows that it contains the same minerals, some of which might almost be termed porphyritic, whilst those in the ground mass or matrix have, in comparison with these, only minute dimensions.

Traces of a gneissic structure are to be seen on the hand specimen.

[7855] Sec. 990. FINE-GRAINED GNEISSIC GRANITE. From ¾ mile east of Ebano Spring.

This rock is similar to [7653] in structure, but shows more gneissic bandings; the colour, too, is many shades darker. Microscopical examination shows that it is a portion of the same rock mass which, having been subjected to more metamorphic action and alteration by weathering, seems at first sight to have been derived from a different rock mass. The minerals have separated out into bands, the felspar is very cloudy and highly altered. Still it is necessary to give the rock a name different from that given to its allies.

[7704] Sec. 995. HORNBLENDE GNEISS. From the Irwin River Falls.

This rock has a decidedly schistose or gneissic appearance, and shows the banded arrangement of the constituents to great perfection. Under the microscope it shows that at one time it was a rock closely resembling [7855, etc.], but owing to metamorphic action so many changes have taken place and so much secondary hornblende has been formed that the mass has become a hornblende gneiss.

The constituents are hornblende, quartz, felspar, and epidote.

[6661] Sec. 718. QUARTZ FELSPAR PORPHRY. 1 mile south of Tibraddon Homestead.

Phenocysts of quartz, orthoclase, and probably plagioclase are abundant, set in a fine grained mass of felspar and biotite. Two peculiarities in structure are to be noted, (1) the biotite is often thickly congregated round the quartz phenocysts, (2) the quartz and felspar are pegmatitic in one or two small areas.

Group II.--**Granites, etc., with inclusions of secondary accessory minerals.**

[8067] Sec. 994. GARNETIFEROUS GRANITE (slightly Gneissic). From Loc. 2229, 1½ miles south of Brown's Tableland.

This is a fine grained mottled rock; the prevailing colour is light grey, but the whole surface is covered with minute red specks (garnets)

and small dark flakes of biotite mica. Under the microscope it i to be an entirely different rock from those just described. We much clear quartz, slightly cloudy felspar (no microcline), and b mica in long flakes with ragged extremeties. As secondary and acce minerals we have pink garnets, zircons, iron ores, tourmaline, etc. structure of the rock, too, differs from [7855], etc. We here all the chief minerals in crystals of a uniform size, and we the fine grained base so characteristic of the other group.

[7872] Sec. 986. GARNETIFEROUS GRANITE (slightly Gneiss From the east branch of the Ikewah Brook.

This rock is similar to [8067], but as it contains more of secondary biotite and other minerals and inclusions, etc., it is n darker in colour. The cloudy felspar, too, is much less abundant, hav probably been altered and changed into the biotite, etc., mentio above.

[4912] Sec. 988. GARNETIFEROUS GRANITE (slightly Gneissic From M.L. 12, near Arrino Railway Station.

This rock is slightly darker than [7872] and exhibits more eviden signs of a gneissic structure. Under the microscope the general appear ance is seen to be similar to the preceding rocks, [8067], [7872] but the scarcity of garnets and the greater predominance of zircons tourmaline, etc., is very noticeable. This rock is evidently one stage further along the line joining the true granites of the district with the hornblendic or biotite gneisses or schists.

[5235] Sec. 987. GARNETIFEROUS GRANITE (slightly Gneissic). From track to Granite Hill, ¼ mile east of railway opposite Yandanooka Homestead.

Similar to the preceding, but so full of secondary biotite, garnets, etc., that it almost seems to be a different class of rock. The microscopic examination shows that green biotite and hornblende are the most conspicuous minerals present. Quartz is also abundant, but felspar is almost entirely absent. Pink garnets of large size but simply one mass of inclusions, are plentiful. Tourmaline and zircons are also present in force. Iron ores are also represented.

[6658] Sec. 984. GNEISSIC GRANITE, with garnets, zircons, etc. From Loc. 2485, Grant's Well, Yandanooka.

This is a typical gneissic rock of a rather coarse texture, showing many crystals of clear quartz, pink orthoclase (?), felspar, green hornblende, and muscovite and biotite micas. With the microscope we see the usual style of quartz, perfectly clear and containing numerous inclusions, those of tourmaline (in long slender prisms and needles) being of fair dimensions. Zircons are also to be recognised among the many small enclosures. The felspar is cloudy and is taken to be orthoclase, for no examples of repeated twinning are to be seen amongst the many crystals examined. A few pieces of plagioclase are also present, and give examples of the albite plan of twinning. Biotite, muscovite, and secondary hornblende are very common. These different minerals being often intergrown. Garnets fairly free from inclusions; zircons and tourmaline, etc., are present.

Group III.—Intermediate and Basic Rocks.

[7707] Sec. 985. HORNBLENDE GNEISS or SCHIST (probably a basic rock). From the summit of Peterwangy Hill.

This is a very hornblendic rock much resembling the gneissic granites described, but the texture in this case is so fine that the name horn-

endic schist would be almost equally appropriate. Its colour is a uniform blue black, and it shows on its surface many small glistening plates and fine surfaces of hornblende. Under the microscope it is seen to consist of green hornblende, plagioclase, felspar—showing much repeated twinning—quartz, augite, and accessory minerals and inclusions. Chloritic material is also present. Though this rock is termed a hornblende gneiss or schist it might equally well deserve the name of quartz diorite. It cannot be associated with any of the rocks in Groups I. and II., but bears some resemblance to the following [7708].

[7708] Sec. 989. ALTERED DIABASE. From the north side of Peterwangy Hill.

This rock is of a rather compact nature, only a few lath-shaped crystals of plagioclase felspar being visible to the naked eye. Its colour, too, is remarkably uniform, viz., a deep blue black or green black. Under the microscope we see that we are dealing with a typical altered diabase. The main constituent is a fairly fresh lath-shaped plagioclase giving fine examples of twinning on both the Carlsbad and Albite plans. The crystals are idiomorphic, and show the characteristics associated with the more basic rocks. The ferro-magnesian mineral has evidently, from its structure, been augite which has undergone so much change that it is now only represented by small cores of the mineral surrounded by secondary hornblende and green chloritic mineral, the whole mass forming a matrix for the felspar. In other places the altered felspar (orthoclase, etc.), forms a very cloudy and highly altered mass in which are placed pieces of quartz augite and less altered orthoclase. In some places a good deal of iron ore is present by its association with the green chloritic matter, pointing to the decomposition of ferro-magnesian minerals. Many parts of the slide show that the rock had a tendency to assume an ophitic structure, the ferro-magnesian mineral surrounding and including the felspar—a fact which also points to the earlier crystallisation of the felspar.

[8808] Sec. 1010. BASALT. 4 miles north of Newmarracarra.

The structure is that of a typical basalt without olivine. The ground mass consists of very small crystals and grains of triclinic felspar, augite, and magnetite; in it are embedded numerous transparent colourless phenocrysts of felspar and some pale brown phenocrysts of augite. No olivine or glass observed.

[8811] Sec. 1012. DIABASE. 4 miles easterly from Narra Tarra Homestead.

A typical rock with ophitic structure. The two main constituents are clear unweathered felspar (triclinic) and pale brown augite. Much iron ore present, part at least of which is ilmenite, as shown by development of a little rutile in association with it. A very little green hornblende pseudomorphous after augite.

[8829] Sec. 1013. NORITE. Loc. 2769, 1½ miles south-easterly from Norman's Well.

Coarse grained mixture of colourless enstatite and very clear unaltered plagioclase. A fair amount of dark brown biotite present in small and large scales. A little magnetite.

[8810] Sec. 1011. NORITE. Loc. 47/538, about 3½ miles easterly from Narra Tarra Homestead.

Similar to [8829], but enstatite showing evidences of alteration and biotite is much more plentiful. Numerous rods of apatite represented.

Group IV.—Sedimentary Tuffs and their allies.

There are five specimens which may be included in this gr though they, with the exception of [4244], show a uniform texture, are all more or less chocolate coloured, still microscopical examinat shows that they vary in composition. Some of them [7580] practically pure sedimentary tuffs, whilst others [7583] contain much quartz that they may equally well be classed as tuffaceous sa stones or shales. The presence of the numerous quartz grains shows t these beds have been deposited under water, in that way differing fr many tuffs which are of aerial origin, and in the formation of wh running water has taken no part. Beds similar to these from the Irw River District have been known at Kiama, in New South Wales, many years, where the same gradations from nearly pure tuffs tuffaceous sandstones, etc., and finally true sandstones and shales, ha been noticed by the officers of the Geological Survey (see Records of th Geol. Survey of New South Wales, Vol. VIII., pt. I., p. 5, etc.). Similar conditions in the district under review would tend to cause the formation of similar beds, and would explain the variation in composition of the rocks. The many reddish and dark grains present are possible altered ferro-magnesian minerals.

[4244] Sec. 1000. Conglomerate Tuff. From M.L. No. 12. near Arrino Railway Station.

This is a true conglomerate. In a chocolate coloured groundmass or matrix are numerous rounded pieces of granite, gneiss, garnet, schist and other igneous rocks, as well as large rounded crystals of pink felspar and quartz and flakes of mica. The microscope shows that some of the included pieces of granite come from the rock mass of Group II. (see specimen [6658], Sec. 984). This, together with the similarity of the matrix of the tuffs and this rock, leads to the conclusion that the tuffs are of more recent age than the Group II. granite mass, a fact which may be of use in determining the ages of both beds or rock masses.

[7580] Sec. 983. Tuff. From Loc. 2899, Arrino.

This is a reddish chocolate coloured rock with darker bands. It has a very uniform texture and is easily scratched with a knife. When breathed upon it has an argillaceous odour. Under the microscope it is seen to be composed of numerous angular grains of quartz and felspar, along with iron ores and pieces of glass in a matrix which has the appearance of devitrified glass and which, judging by the chemical analysis of the rock, must be very felspathic.

[7586] Sec. 981. Tuff. From well in M.L. 30, Arrino.

This is a chocolate coloured tuff which, upon microscopical examination, is seen to greatly resemble [7580], though it does show less of the matrix and a correspondingly higher percentage of quartz and felspar grains.

[6360] Sec. 980. Tuff. From well in Loc. 2488, Arrino.

This tuff is rather darker than the preceding. Microscopically it shows a uniformity of grain and a greater abundance of quartz and felspar, but hardly any "matrix," simply a "cement."

[7583] Sec. 982. Tuff (arenaceous). From $\frac{1}{2}$ mile east of Arrino Railway Station.

This tuff is similar to the rest of this group, but shows many small plates of mica in the hand specimen. As it is harder, too, it is probable that it contains a fair amount of quartz, which would make this an example of a tuff gradually shading off into a fine grained sandstone or shale. The microscopical examination brings out no new points, and therefore need not be gone into here.

Group V.—**Quartz-Breccias and Sandstones.** (Sedimentary continued). Age undetermined.

[7581] Sec. 796. QUARTZ-BRECCIA. From well in Reserve 8725, Arrino.

This is a pale greyish quartzite-like rock showing numerous angular grains of variously coloured quartz with pink orthoclase, felspar, and greenish yellow chlorite or epidote. Under the microscope we see we are dealing with a typical quartz-breccia composed almost entirely of angular quartz cemented together by a silicious cement.

[7602] Sec. 861. SILICIFIED GRIT, Arrino.

Composed of coarse, angular quartz grains cemented with clay, the latter at times slightly iron-stained and so impregnated with secondary silica as to be porcellaneous. The whole rock hard and possessing conchoidal fracture. Some of the quartz grains are full of rutile needles.

[7877] Sec. 866. QUARTZITE. Billeranga.

Rounded quartz grains from one-fortieth of an inch downwards in diameter, many containing needles of rutile, cemented with secondary quartz stained red with iron oxide. A little clay in places in the cementing matter.

[7847] Sec. 860. QUARTZITE (silicified quartz-breccia?). Mt. Melara stray block.

Large and small pebbles and grains of quartz and chalcedony, partly rounded, partly angular. Cementing material, clay, and secondary silica (chalcedony). A little green chlorite and iron oxide associated with the clay; some of the largest pebbles consist of a core of coarsely crystalline quartz with a border of chalcedony.

[7693] Sec. 857. SILICIFIED ARGILLACEOUS SANDSTONE. Carboniferous. Gnoolowa Hill.

Quartz in well rounded grains from 1/50 inch to 1/500 inch in diameter, embedded in a base of very fine grained quartz and clay, wholly impregnated with secondary silica, rendering whole of rock hard and giving it a sub-conchoidal fracture. Large quartz grains frequently contain numerous spicules of rutile.

[7845] Sec. 858. SILICIFIED (INDURATED) CLAYSTONE. Irwin River, south-east of Nangatty.

Fine grained clay with occasional small grains of quartz, the whole indurated by development of a little secondary silica.

[7691] Sec. 859. SANDSTONE PARTLY SILICIFIED. Two mile south-west of Nangatty.

The greater part of this rock is a firm argillaceous sandstone o medium grain. Irregular masses of it are completely silicified to a rock identical with [7602]. A section of one of these masses shows it to consist of rounded quartz grains with rutile needles, embedded in a porcelain-like mass of silicified clay.

Jurassic (?)

[7865] Sec. 856. QUARTZITE. Billeranga Plains.

Composed of closely packed quartz grains averaging about 1/300 inch in diameter, rounded or subangular, cemented with original grains. Occasional granules of felspar present, and a little iron oxide in cementing material. Rock has a conchoidal fracture.

Jurassic.

[8059] Sec. 865. SANDSTONE. Mt. Hill.

Fine subangular grains of quartz, felspar, and ferruginous material cemented by clay, iron oxide, and secondary silica.

[8057] Sec. 868. SILICIOUS SANDSTONE or FINE GRIT. From Mt. Hill.

This is a fine grained grit or rather coarse grained sandstone composed of water-clear quartz in a more or less ferruginous siliceous cement. Under the microscope the rock shows all the characteristics of a siliceous sandstone, the numerous subangular and rounded grains of quartz and a little felspar are in a cement of iron-stained silica. Some of the quartz grains have large, and all have small, inclusions.

[8060] Sec. 867. FERRUGINOUS SANDSTONE. From Mt. Hill, ¾ mile south.

This is a typical purplish fine grained sandstone which, upon examination under the microscope, is seen to consist of uniform rounded grains of quartz in a ferruginous cement. A little felspar and muscovite are also present.

Tertiary.

Group VI.—**Limestones** (Sedimentary continued).

[8030] Sec. 996. FOSSILIFEROUS LIMESTONE. From Reserve 7469, Irwin Siding.

This is a cream coloured limestone showing traces of stratification but no signs of organic remains when examined with the naked eye. Under the microscope the rock has a decidedly yellow tint, and though the section is thick it is possible to recognise traces of organic remains and to make out angular and subangular grains of quartz and felspar as well as fragments of brown biotite and other mineral matter.

[8032] Sec. 998. ARENACEOUS FORAMINIFERAL LIMESTONE. From Loc. 839, Yardarino.

This is a cream coloured limestone like [8030], a type so well known on the coastal districts in the vicinity of Perth. To the naked eye it appears to be a sandy limestone without any organic remains. The microscope, however, shows the rock to consist essentially of calcium carbonate in the form of foraminifera shell fragments, etc., and rounded and subangular grains of quartz and felspar cemented together by a calcareous cement.

The organic remains are so fragmentary that it is impossible to distinguish genus or species of the foraminifera.

[8043] Sec. 997. ARENACEOUS FORAMINIFERAL LIMESTONE. From N. of Loc. 1714, Dongara.

This rock resembles [8032], but has a much higher percentage of sand. It also is full of organic remains, which, however, are only revealed when the microscope is used upon the section. There is not the slightest doubt about the presence of foraminifera, for many perfect ones are to be seen in the slide. They will be studied when the rest of the rocks have been described, if circumstances allow.

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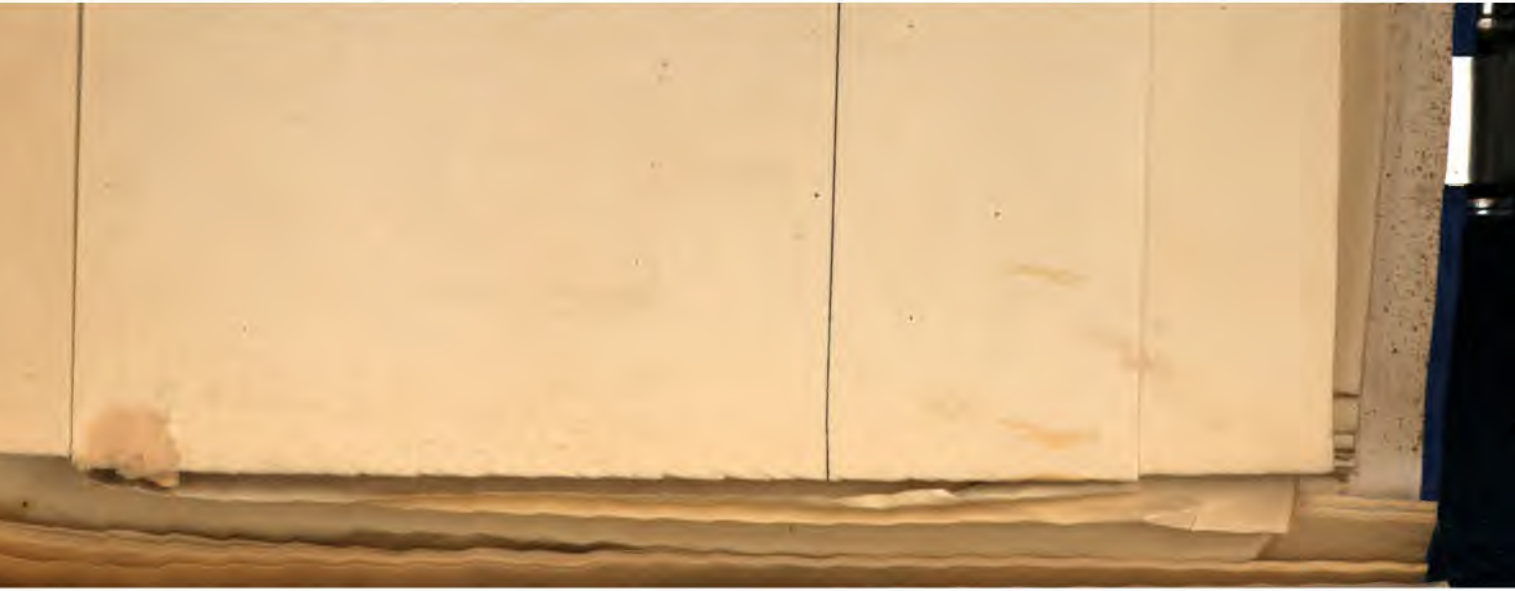

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